FIELD INVESTIGATIONS OF UNCONTROLLED HAZARDOUS WASTE SITES

FIT PROJECT

TASK REPORT TO THE ENVIRONMENTAL PROTECTION AGENCY CONTRACT NO. 68-01-6056

INTERIM REPORT
ON THE
GROUNDWATER QUALITY
OF
EAST AND NORTH WOBURN, MASSACHUSETTS

May 6, 1981
TDD No. F1-8010-04B

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Field Investigation Team (FIT)
Region 1

Submitted to: John Hackler

ecology and environment, inc.

International Specialists in the Environmental Sciences

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Contributors

Ecology and Environment, Inc.
Region 1 Field Investigation Team

TDD # F1-8010-04B

Interim Report on the Groundwater Quality
of
East and North Woburn, Massachusetts

The following Region 1 Field Investigation Team members made major contributions to this study in the capacities noted:

Project Manager	-	David Cook
Sampling and Analysis	-	Paul Clay
Toxicology	-	Anne Marie Desmarais
Data Interpretation	-	David Cook, Richard DiNitto

SECTION 1 - INTRODUCTION

1.1 PURPOSE

To gather groundwater quality data for East and North Woburn, Massachusetts to be used in conjunction with reports on the geology (TDD #F1-8010-02A) and hydrology (TDD #F1-8010-03A) of the area. This data will be used to determine and recommend appropriate remedial actions to be performed using funds provided by the Hazardous Waste Containment Act of 1980.

1.2 OBJECTIVE

1.2.1 To perform sampling and priority pollutant analysis of thirty-two (32) wells in East and North Woburn.

1.2.2 To construct areal contamination distribution maps consistent with the groundwater and subsurface geologic data gathered under TDD's #F1-8010-02A and F1-8010-03A.

1.2.3 To provide human health effects data regarding all detected contaminants.

SECTION 2 - SITE BACKGROUND

This report was written in response to TDD #F1-8010-04B tasking the Ecology and Environment, Inc. (E & E) Region I Field Investigation Team (FIT) to sample all accessible wells in North and East Woburn, Massachusetts, have priority pollutant analyses performed for each sample, and present the results in a formal report. This report is a companion report to an earlier study performed by the Region I FIT entitled "Interim Report on the Geology and Groundwater of North and East Woburn, Massachusetts, 3 April 1981" and will be supplemented by analytical data from 20 proposed monitoring wells. The combined efforts in Woburn are aimed at developing appropriate remedial actions to be funded under the Hazardous Waste Containment Act of 1980.

Figure 1 shows the location of the study area covered by this report and the geology and groundwater report. Other investigations by the Region I FIT entitled "Inventory of Wells in the Woburn, Massachusetts Area, 2 June 1980, TDD # F1-8005-01" and "Inventory and Analysis of Existing Well Data for East and North Woburn, Massachusetts, 9 January 1981, TDD # F1-8010-03" identified the accessible wells sampled during this study. The locations of the wells sampled and the twenty proposed wells are noted in Figure 1. Figures 1A through 1F are November 1980 air photos showing the locations of the sampling points.

A brief history of the study area is included in Section 2 of the geology and groundwater report. A more detailed history of specific sites may be found in References 1 to 6.

All wells, with one exception, were sampled between November 12, 1980 and March 2, 1981 by the Region 1 FIT and sent to an EPA national contract laboratory for analysis. The exception, Well AG-4A, was closed in the summer of 1980 due to high levels of contamination detected in an analysis performed on June 27, 1980 at the Massachusetts Department of Environmental Quality Engineering, Lawrence Experiment Station. This analysis was used for this study since the well is no longer accessible.

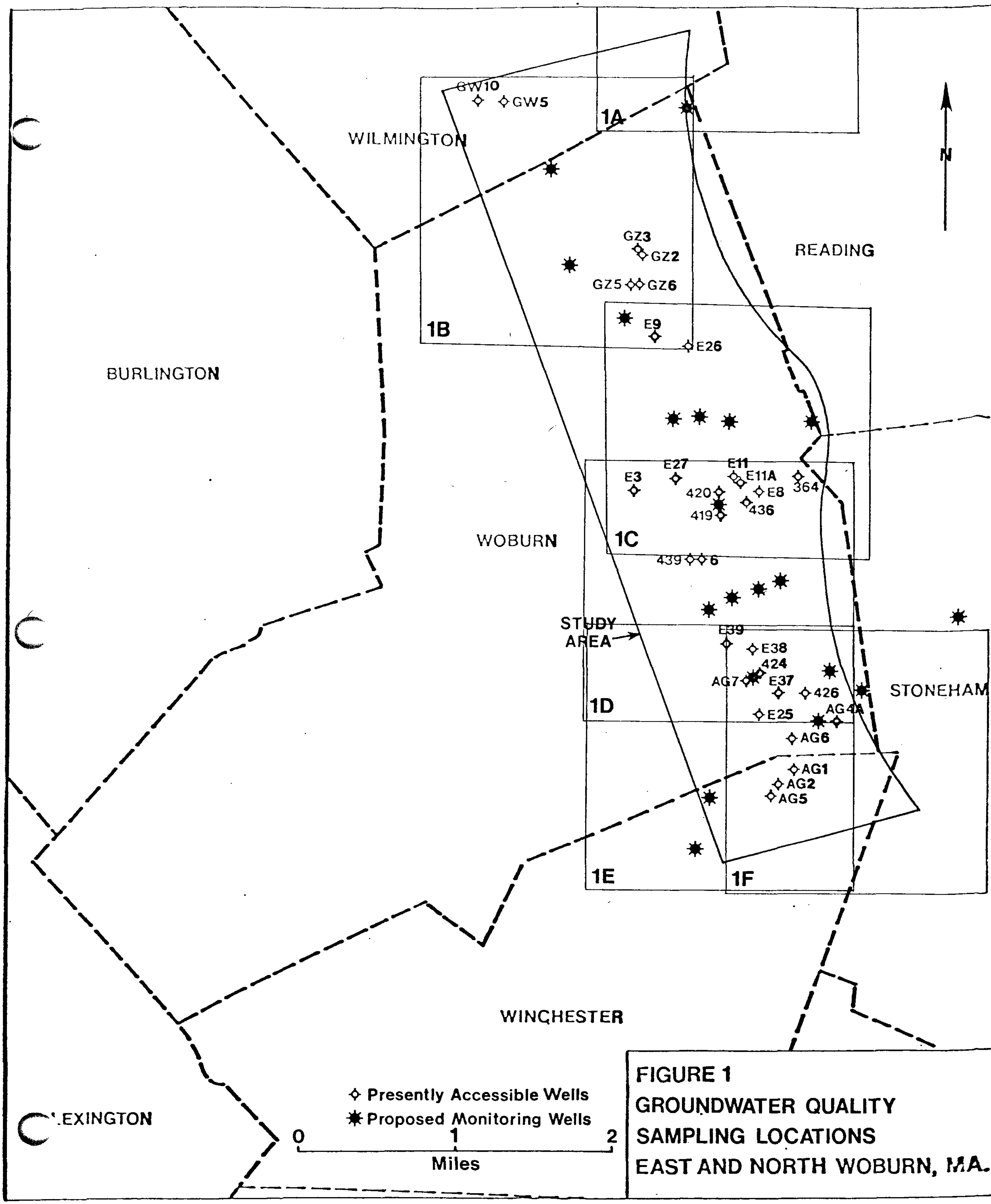


FIGURE 1
GROUNDWATER QUALITY
SAMPLING LOCATIONS
EAST AND NORTH WOBURN, MA.

FIGURE 1A: 1980 Aerial Photograph of a Portion of North Woburn, Massachusetts

Scale: 1:9600

FIGURE 1B: 1980 Aerial Photograph of a Portion of North Woburn, Massachusetts

Scale: 1:9600

FIGURE 1C: 1980 Aerial Photograph of Portions of North and East Woburn, Massachusetts

Scale: 1:9600

FIGURE 1D: 1980 Aerial Photograph of a Portion of East Woburn, Massachusetts

Scale: 1:9600

FIGURE 1E: 1980 Aerial Photograph of a Portion of East Woburn, Massachusetts

Scale: 1:9600

FIGURE 1F: 1980 Aerial Photograph of a Portion of East Woburn, Massachusetts

Scale: 1:9600

2. Site Background - continued

The purpose of this report is to graphically present the data contained in the priority pollutant analyses. This is an interim report which will be supplemented with analyses of samples collected from the twenty proposed monitoring wells tentatively scheduled for installation by the end of July 1981. No attempt will be made in this report to associate the areal extent of contamination with potential sources.

3.1 ANALYTICAL TECHNIQUES

Samples from all wells were analyzed by the methods described in Reference 9.

Organics Analysis

"With the exception of total phenols, organics fall into four main groups defined by analytical procedures. These are the volatile organics, two liquid-liquid extractable semivolatile organics fractions (base-neutral and acid) and pesticides. The volatile organic analyses (VOA) are conducted by the purge and trap GC/MS method developed by Bellar and Lichtenberg or GC with the selected detectors. With the exception of acrolein and acrylonitrile, all of the volatile organic priority pollutant compounds, at concentrations less than 1,000 ug/l, can be efficiently recovered by the purge and trap method. Acrolein and acrylonitrile are analyzed by direct aqueous injection GC/MS according the ASTM Methods D3371-74T and D2908-74. Direct aqueous injection is also employed for all compounds at concentrations greater than 1,000 ug/l.

"Semivolatile organics are solvent extractable so liquid-liquid extraction techniques consisting of base-neutral and acid extractions are used. Determination of these compounds is by conducted GC/MS methods, or by GC with the selected detectors, or HPLC depending on the particular compound. Extractions from the sample are performed sequentially with the base-neutral extraction preceding the acid extraction. Most of the semivolatile organic priority pollutants are base or neutrally extracted. The acid extraction is for the phenolic compounds. Following extraction and concentration, the sample is injected into the GC/MS.

"Pesticides and PCB's are also solvent extractable and are analyzed first by GC using electron capture (EC). If any pesticides or PCB's are found by EC to be in concentrations greated than 5 ug/l, then they must be confirmed by GC/MS.

"Total phenols is not one of the 129 priority pollutants, although phenol and 10 other specific phenolic compounds (acid extractables) are included. However, priority pollutant analysis usually includes total phenols. Analytical procedures for distillation and colorimetric methods employed for total phenols are described in Standard Methods. For concentrations less than 1 mg/l the direct photometric method is used. (See Figure 2 for a flow diagram of the extraction procedures and analytical scheme used on the semi-volatile organics and pesticides.)

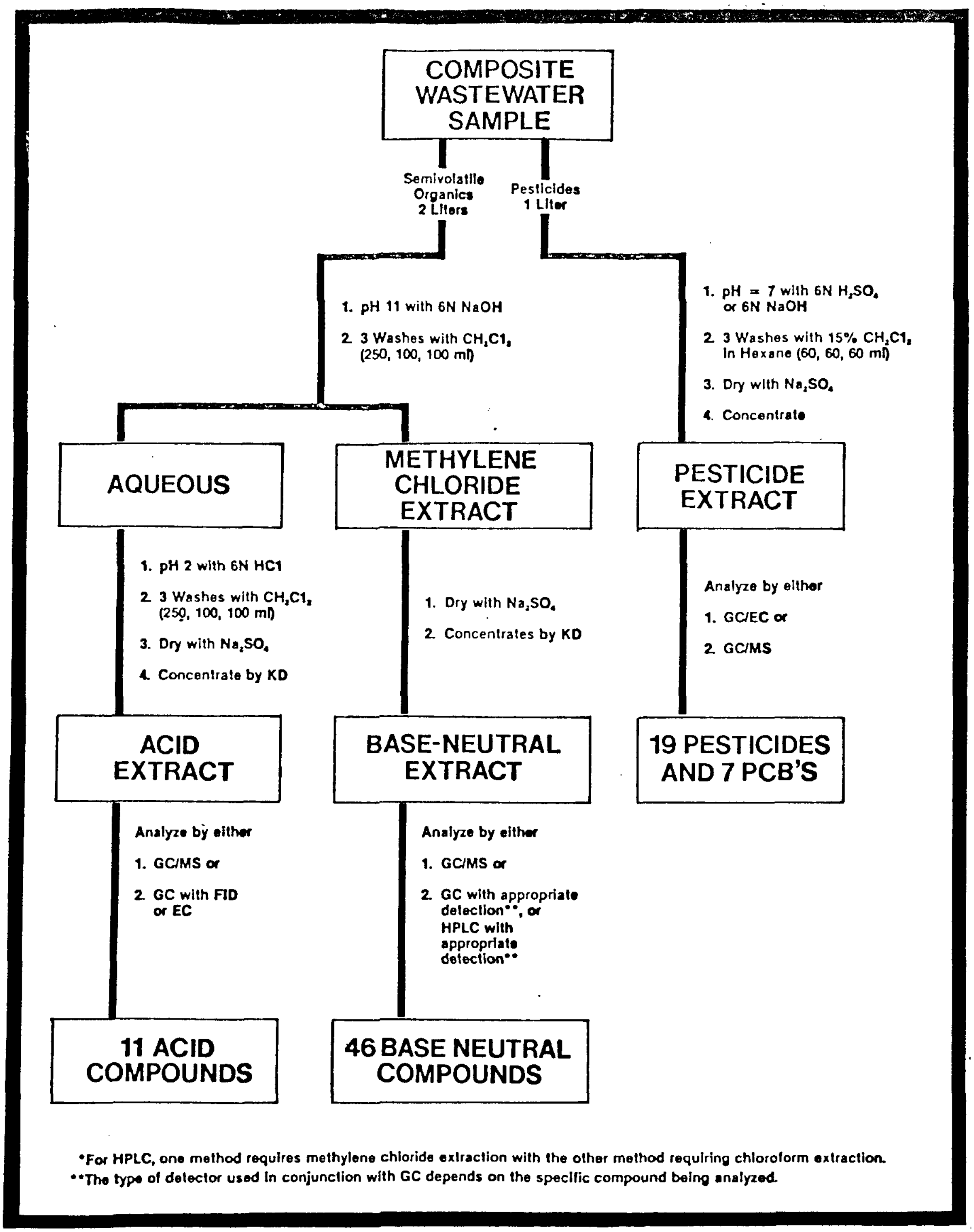


FIGURE 2: Priority Pollutant Analysis Flow Diagram (Reference 9)

3.1 Analytical Techniques - continued

Metal Analysis

"All priority pollutant metals are analyzed by atomic absorption (AA) spectrophotometric methods. Some are determined by flame AA, some are determined by flameless AA, and mercury is determined by the cold vapor technique. The priority pollutant metals are specified as total metals concentrations rather than particulate or soluble metals. However, it is often necessary or desirable to know the particulate and soluble metals, as well as the total metals' concentrations.

"Particulate or suspended metals are those metals which are retained by a 0.45u membrane filter (nonfilterable). Soluble or dissolved metals are those metals which pass through a 0.45u membrane filter (filterable). Total metals is the sum of both the particulate and soluble fractions. Whenever particulate metals are determined, or total metals are determined on an unfiltered sample, digestion is required prior to analysis. Digestion destroys all organic matter and releases the metals into solution. Digestion procedures are described in EPA 'Methods for Chemical Analyses of Water and Wastes' (1979) and in Standard Methods.

"The metals that are determined by flame AA are beryllium, cadmium, chromium, copper, nickel, lead, and zinc. If these metals are not detected or if they are detected at concentrations lower than those shown in the table below they must subsequently be analyzed by flameless AA. The flame AA analytical method and sample preparation procedures employed are described in the EPA 'Methods'.

Lower Limits for Flame AA Analysis

Metal	Analyze by flameless AA if concentration is less ug/l
Be	20
Cd	20
Cr	200
Cu	50
Ni	100
Pb	300
Zn	20

3.1 Analytical Techniques - continued

Metal Analysis - continued

"Silver, arsenic, antimony, selenium, and thallium are analyzed by the flameless AA technique. Except for antimony and beryllium, samples for the flameless AA are prepared as described in the section on "Industrial Waste Effluent" in Atomic Absorption Newsletter, and in Appendix IV of the EPA protocol "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants." The flameless AA analysis for antimony and beryllium requires the same sample preparation procedure as with flame AA.

Cyanides Analysis

"Total cyanides are determined by titrimetric or colorimetric methods described in both Standard Methods and 'EPA Methods'. Prior to analysis, the samples must undergo distillation. For total cyanides concentrations greater than 1 mg/l, the volumetric titration method is employed. For lower concentrations, the colorimetric method is employed.

SECTION 4 - ANALYTICAL RESULTS

The results of the priority pollutant analyses indicate the presence of 42 organic priority pollutants in the groundwater of North and East Woburn. In addition, twenty-two metals were quantified. Following is a list of all organics and inorganics identified, the maximum concentration detected within the study area for each, and the number of wells in which each was detected.

Acid Compounds	Number of Wells	Maximum Concentration (in ppb)
p-Chloro-m-cresol	1	35
Phenol	5	266
4-Nitrophenol	1	2831
Base/Neutral Compounds		
Fluoranthene	2	21
Naphthalene	1	36
N-Nitrosodiphenylamine	2	275,731
Bis(2-Ethylhexyl) phthalate	11	62,524
Butyl benzyl phthalate	2	38
Di-n-butyl phthalate	5	4,226
Di-n-octyl phthalate	7	<10
Diethyl phthalate	6	<10
Anthracene	1	<10
Phenanthrene	1	<10
Pyrene	1	<10
Nitrobenzene	1	2,669
Volatile Compounds		
Benzene	14	76
Carbon tetrachloride	1	11
Chlorobenzene	1	<10
1,2-Dichloroethane	2	82
1,1,1-Trichloroethane	12	611
1,1-Dichloroethane	8	25
Chloroform	6	<10
1,1-Dichloroethylene	4	20
1,2-trans-dichloroethylene	16	210
Ethylbenzene	3	<10
Methylene chloride	15	23
Trichlorofluoromethane	3	775
Tetrachloroethylene	9	89
Toluene	15	106
Trichloroethylene	27	2,290

4. Analytical Results - continued

Pesticides	Number of Wells	Maximum Concentration (in ppb)
Aldrin	2	<5
Dieldrin	1	<5
4,4'-DDT	5	<5
4,4'-DDE	4	23
4,4'-DDD	2	<5
α - endosulfan	2	<5
Heptachlor	2	<5
Heptachlor epoxide	4	<5
α - BHC	5	5
β - BHC	7	<5
γ - BHC	3	<5
δ - BHC	9	<5
Metals		
Aluminum	17	362,000
Chromium	11	2,070
Barium	29	2,160
Beryllium	1	2
Cadmium	4	40
Cobalt	9	250
Copper	17	47,800
Iron	30	637,000
Lead	10	4,550
Nickel	9	360
Manganese	29	17,200
Zinc	27	17,400
Boron	24	3,170
Vanadium	11	640
Calcium	30	513,000
Magnesium	30	95,000
Sodium	30	295,000
Arsenic	8	7,000
Antimony	1	90
Selenium	1	87
Thallium	3	50
Mercury	8	49
Tin	8	300

4. Analytical Results - continued

Figures 3 to 57 are areal distribution maps of all detected organic and inorganic contaminants with the exception of anthracene, phenanthrene, pyrene and chlorobenzene. Each of these four compounds was detected in only one well in quantities of less than 10 ppb as noted below.

Compound	Well
Anthracene	GZ-2
Phenanthrene	GZ-2
Pyrene	GZ-2
Chlorobenzene	439

The areal distribution maps represent only the known extent of contamination. There are many areas with insufficient data because accessible wells were not present. The proposed monitoring wells will provide data to fill the gaps in the existing data.

Analytical data tabulated by sampling location are presented in Appendix A.

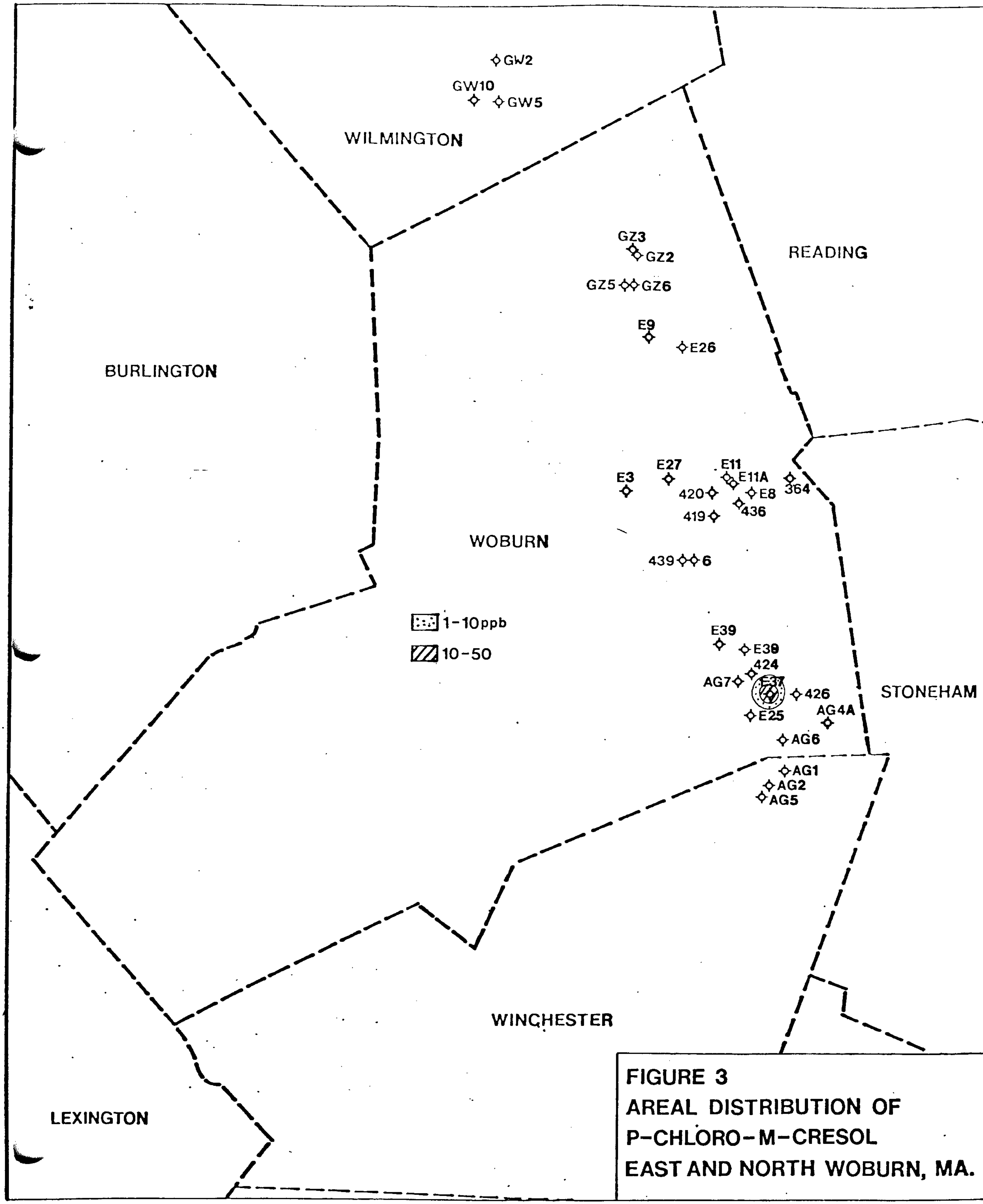


FIGURE 3
AREAL DISTRIBUTION OF
P-CHLORO-M-CRESOL
EAST AND NORTH WOBURN, MA.

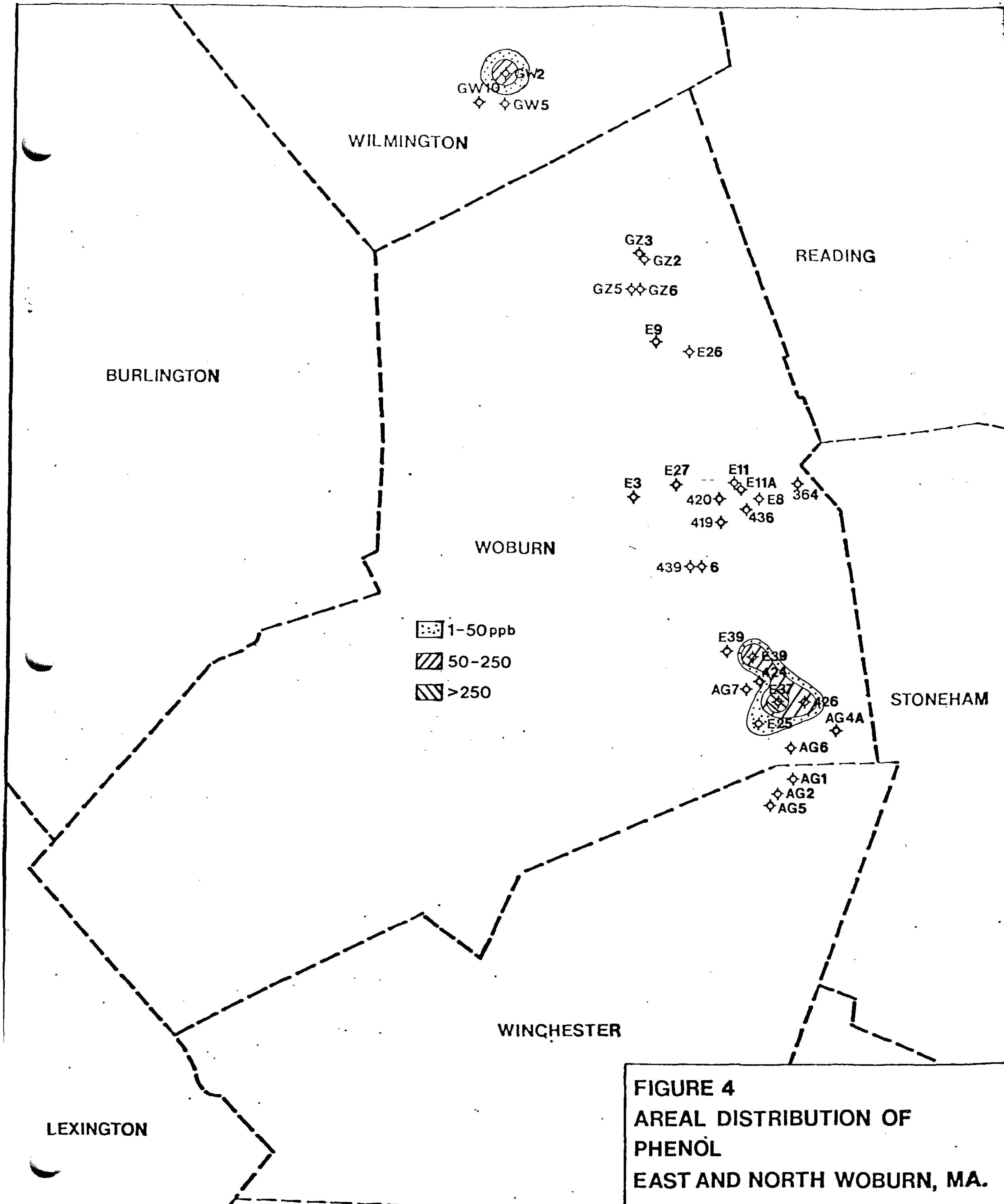


FIGURE 4
AREAL DISTRIBUTION OF PHENOL
EAST AND NORTH WOBURN, MA.

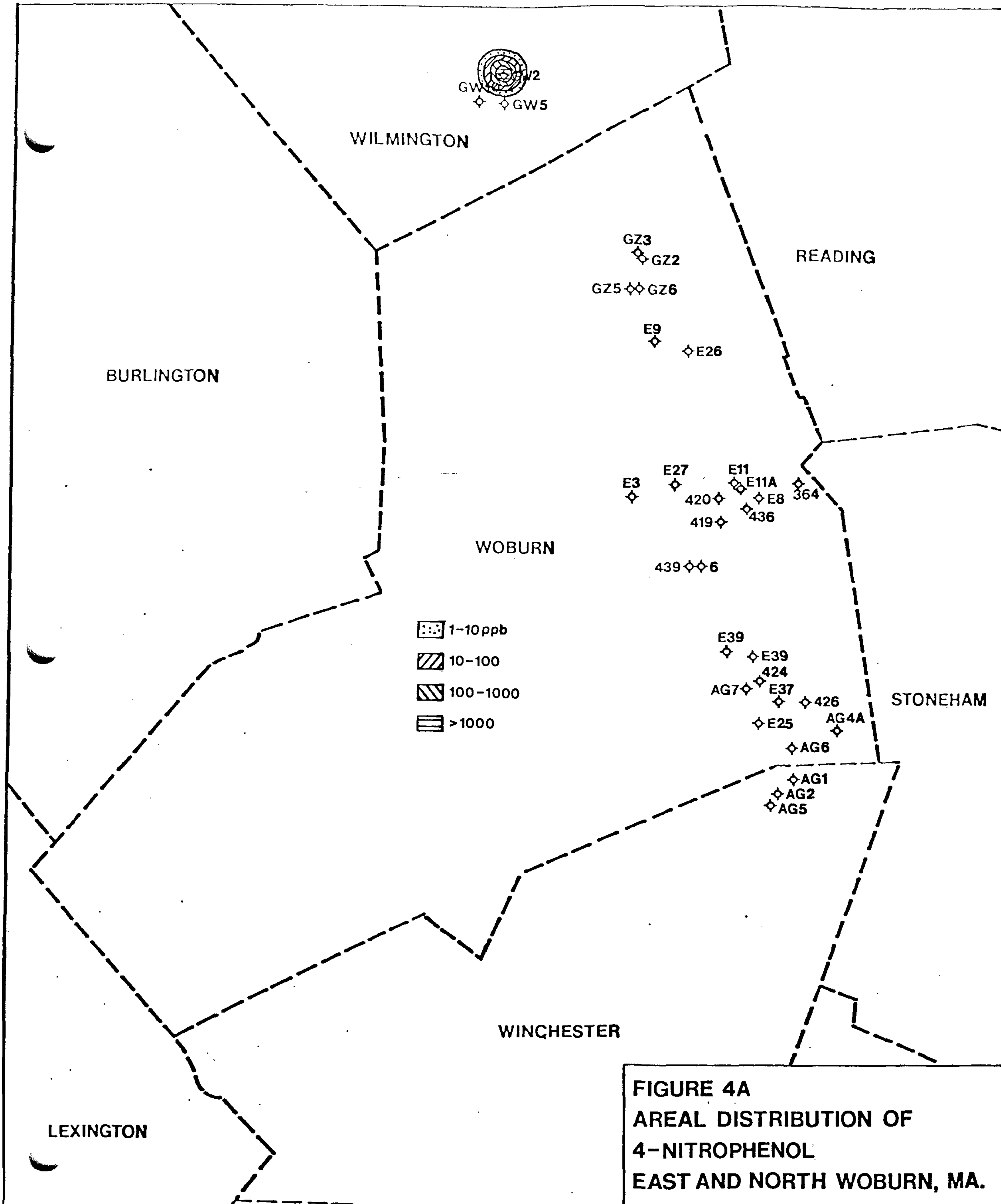


FIGURE 4A
AREAL DISTRIBUTION OF
4-NITROPHENOL
EAST AND NORTH WOBURN, MA.

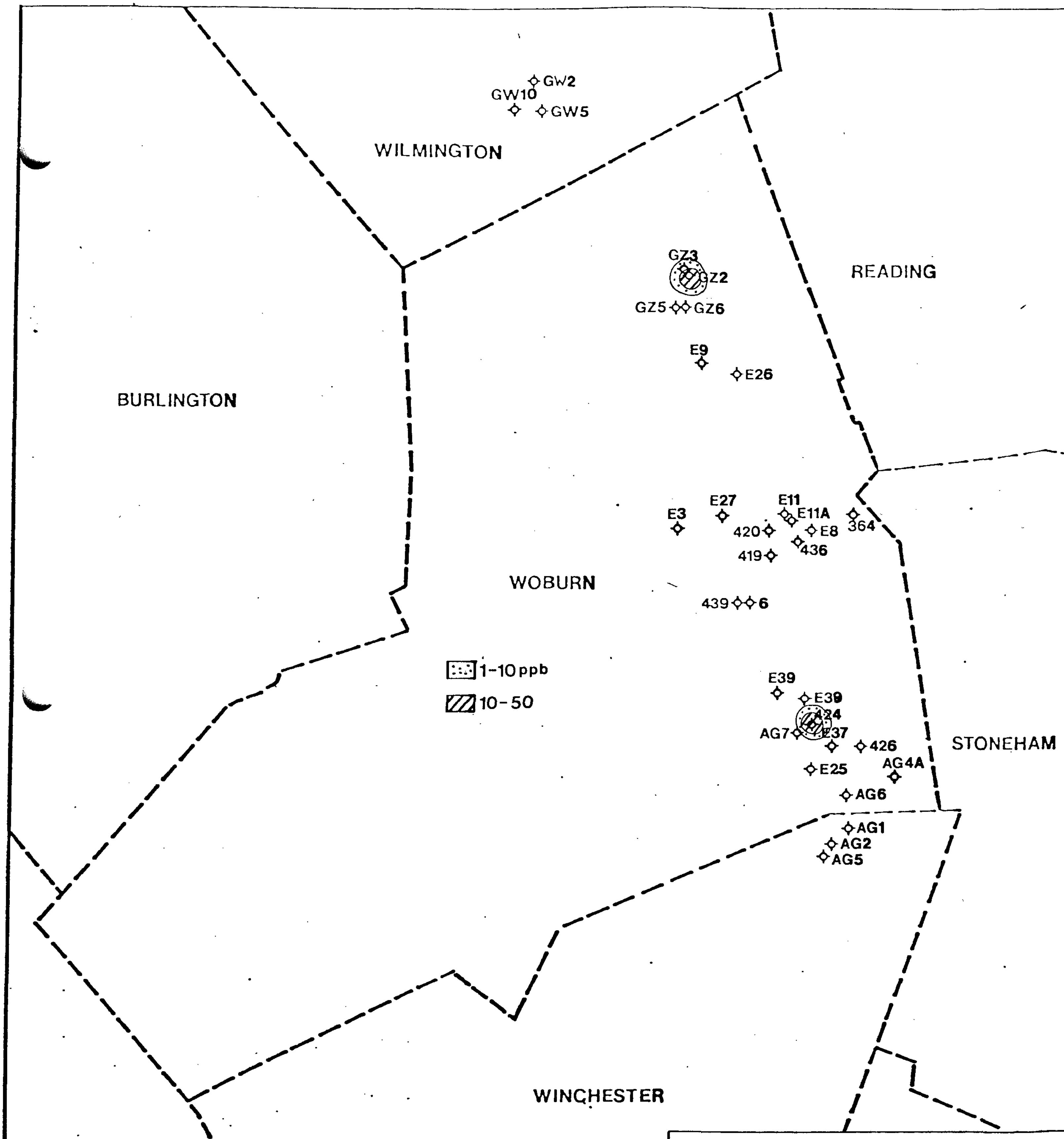


FIGURE 5
AREAL DISTRIBUTION OF FLUORANTHENE
EAST AND NORTH WOBURN, MA.

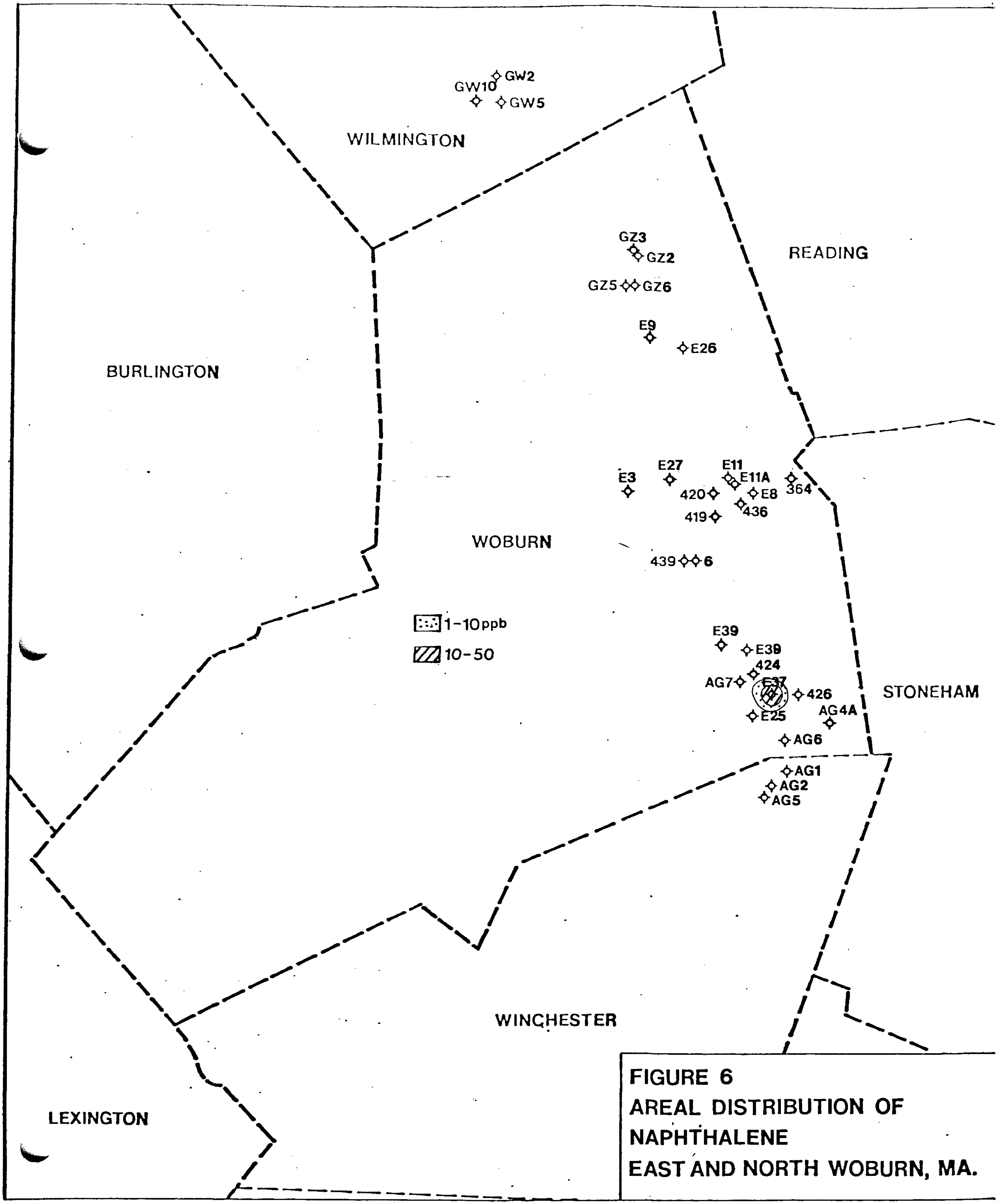


FIGURE 6
AREAL DISTRIBUTION OF NAPHTHALENE
EAST AND NORTH WOBURN, MA.

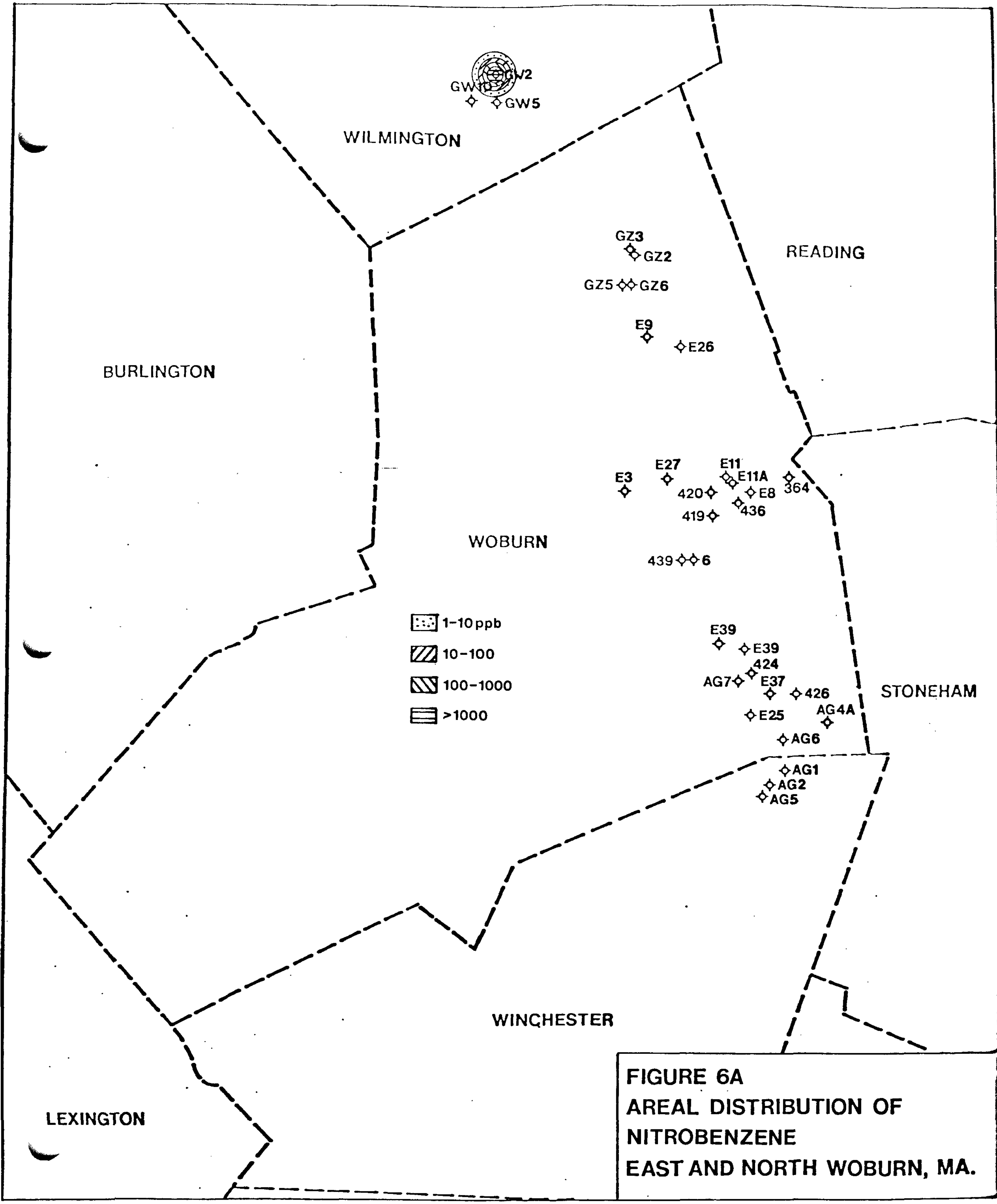


FIGURE 6A
AREAL DISTRIBUTION OF NITROBENZENE
EAST AND NORTH WOBURN, MA.

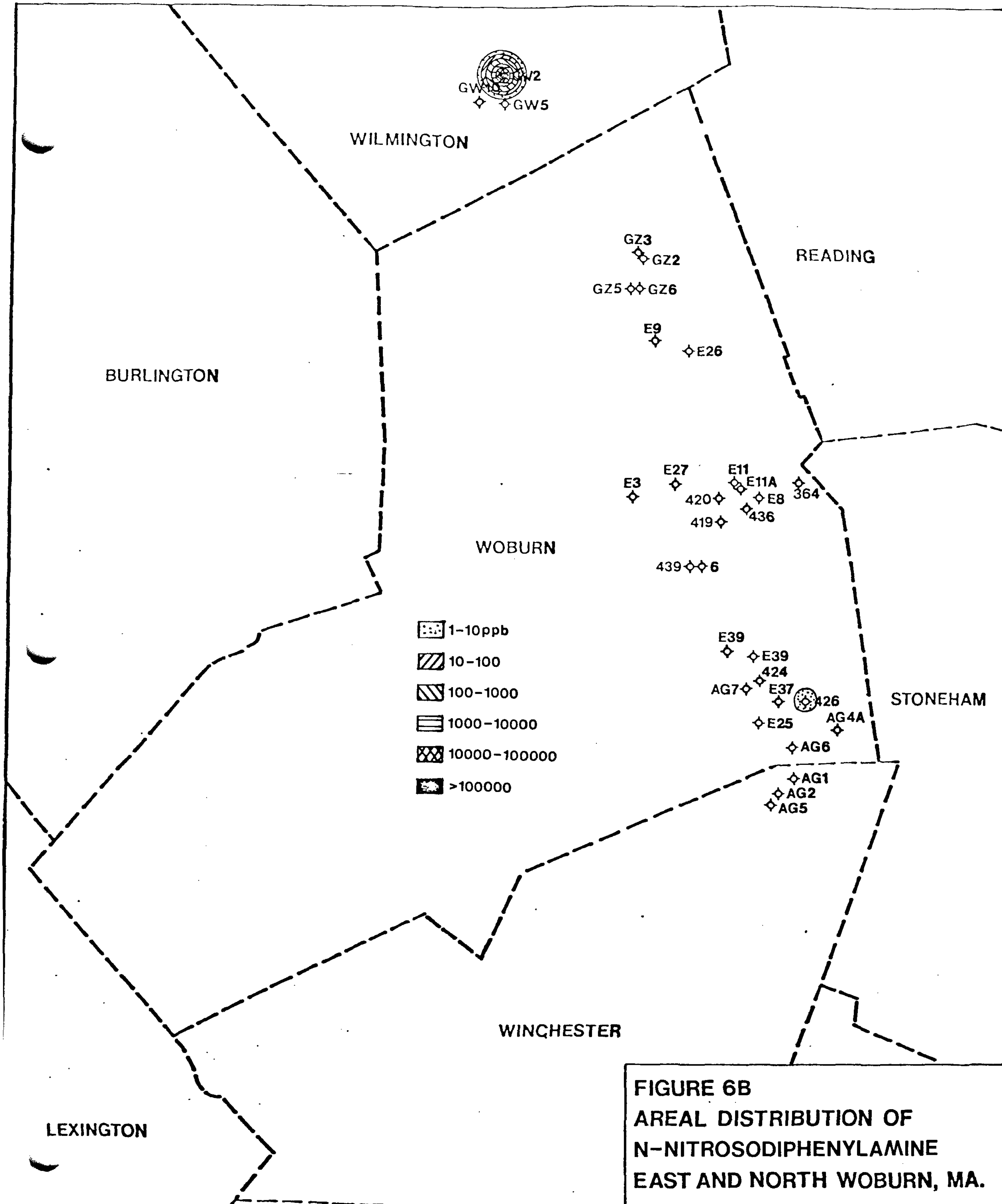


FIGURE 6B
AREAL DISTRIBUTION OF
N-NITROSODIPHENYLAMINE
EAST AND NORTH WOBURN, MA.

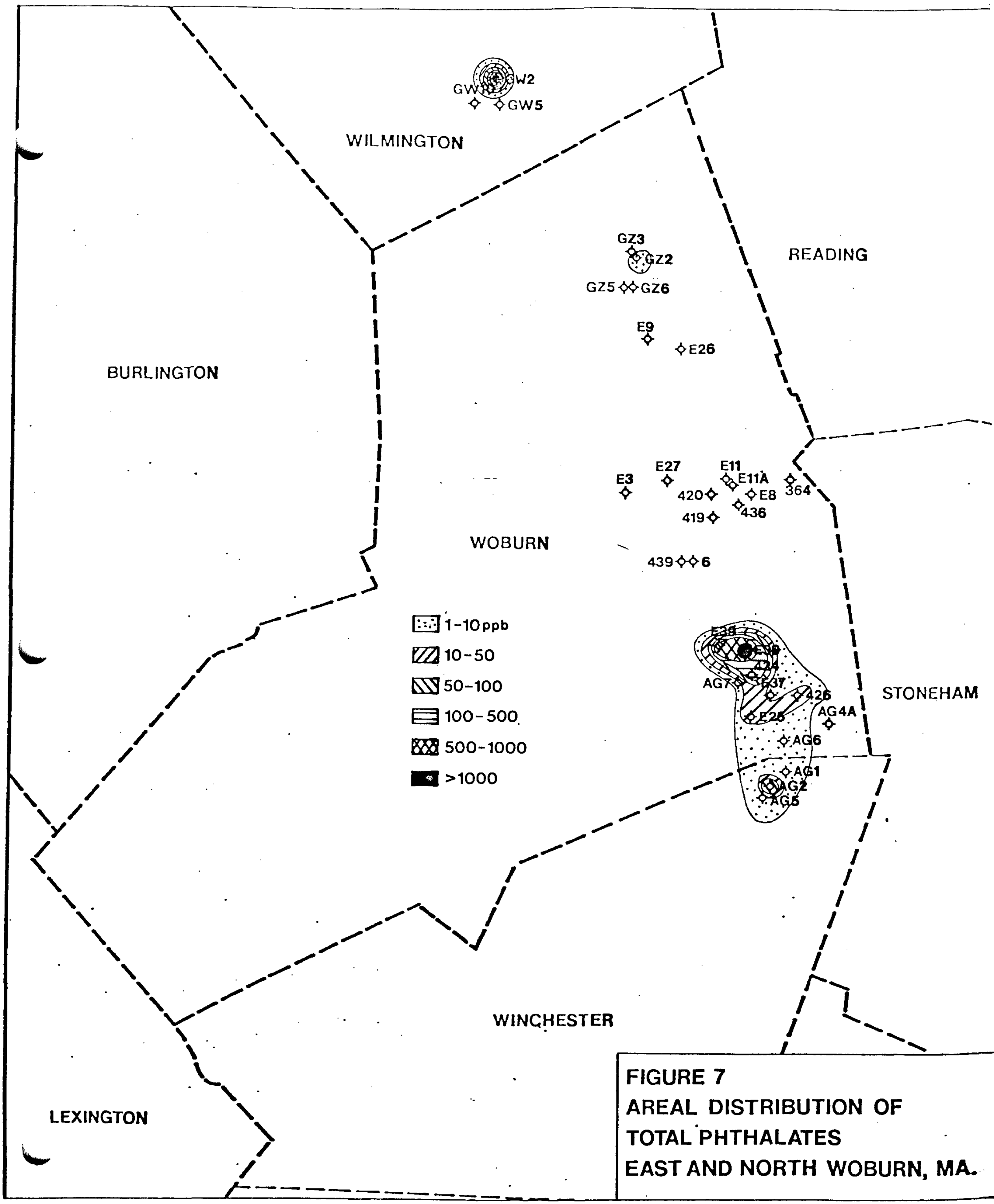


FIGURE 7
AREAL DISTRIBUTION OF
TOTAL PHTHALATES
EAST AND NORTH WOBURN, MA.

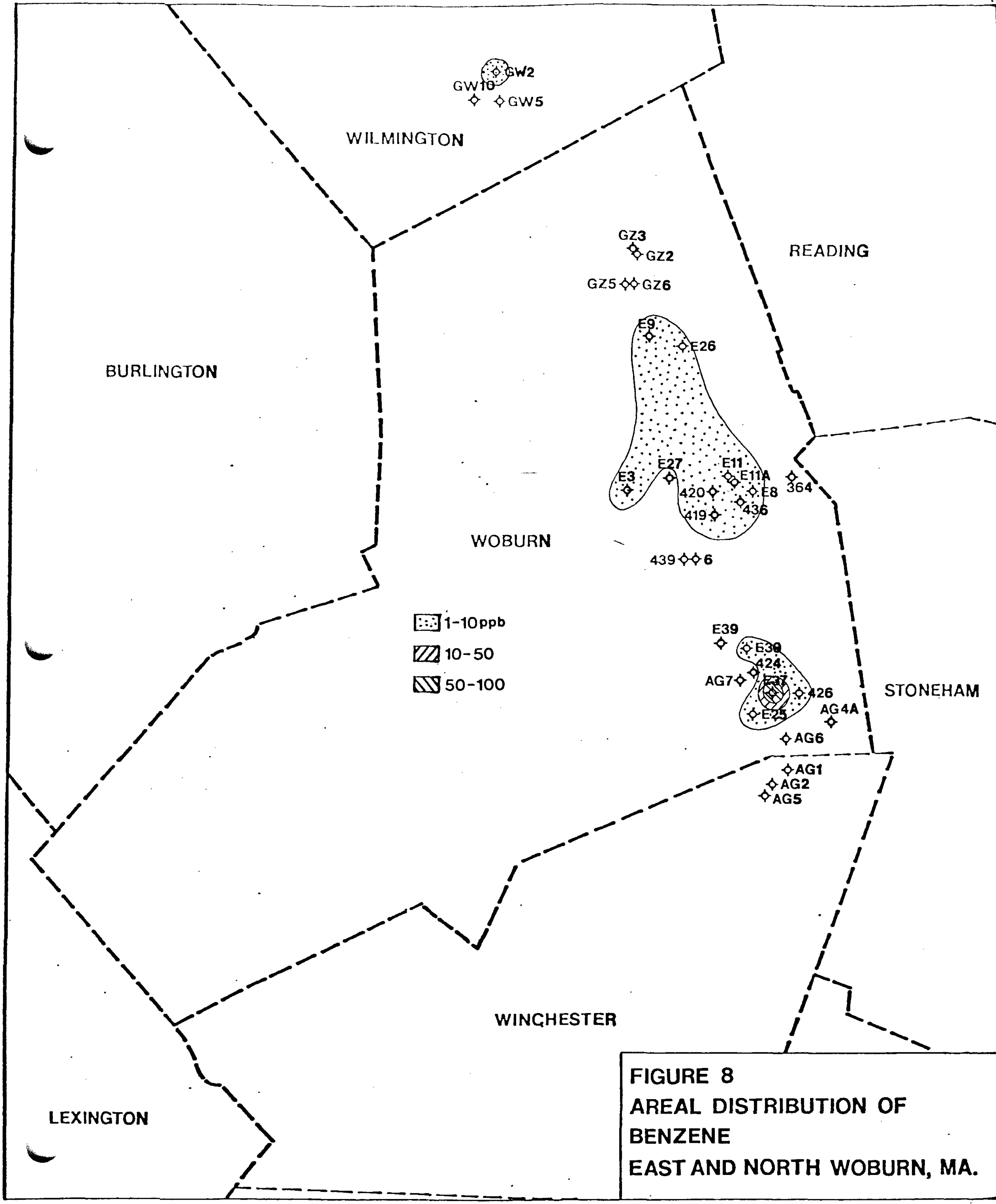


FIGURE 8
AREAL DISTRIBUTION OF
BENZENE
EAST AND NORTH WOBURN, MA.

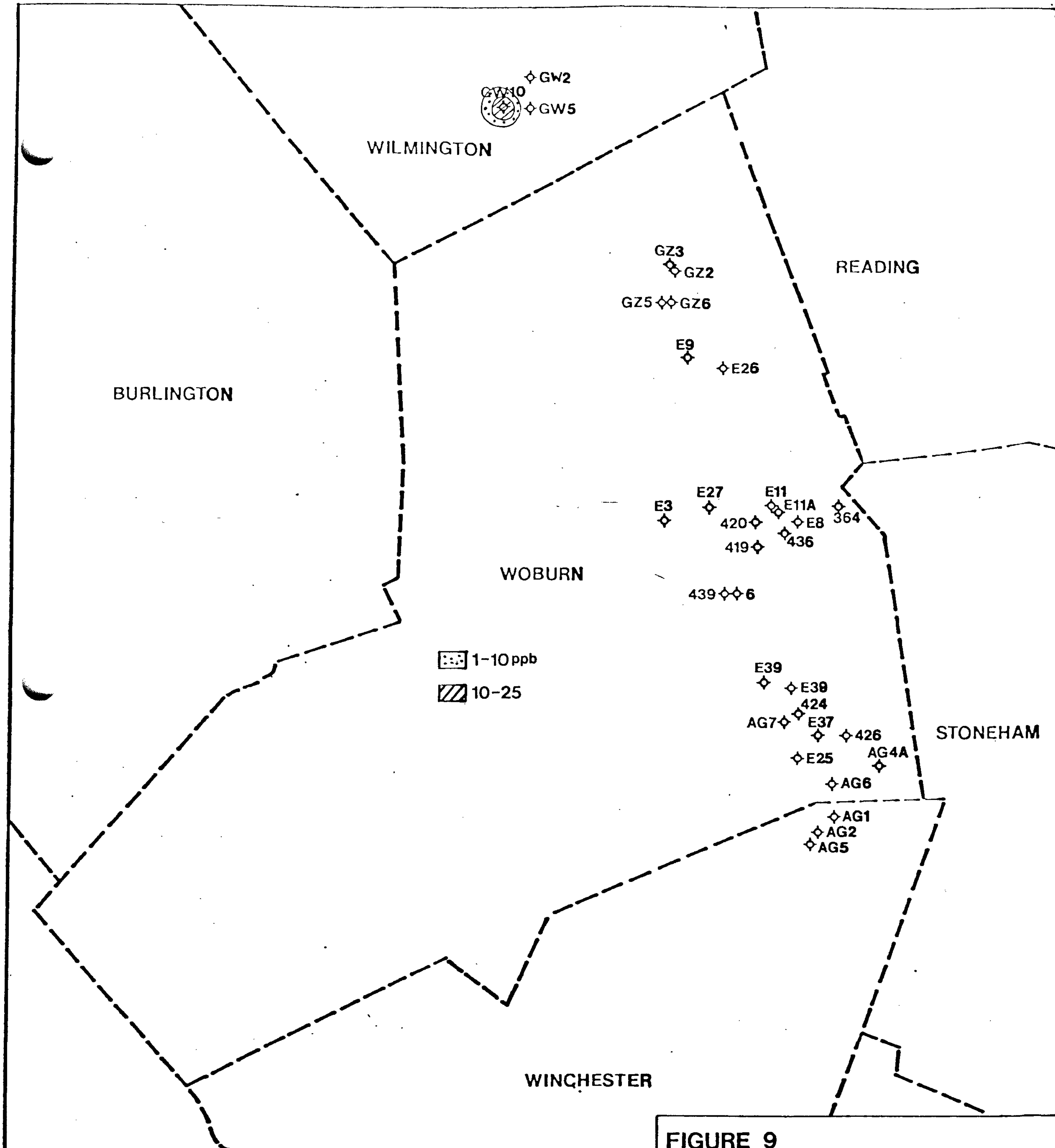


FIGURE 9
AREAL DISTRIBUTION OF CARBON TETRACHLORIDE EAST AND NORTH WOBURN, MA.

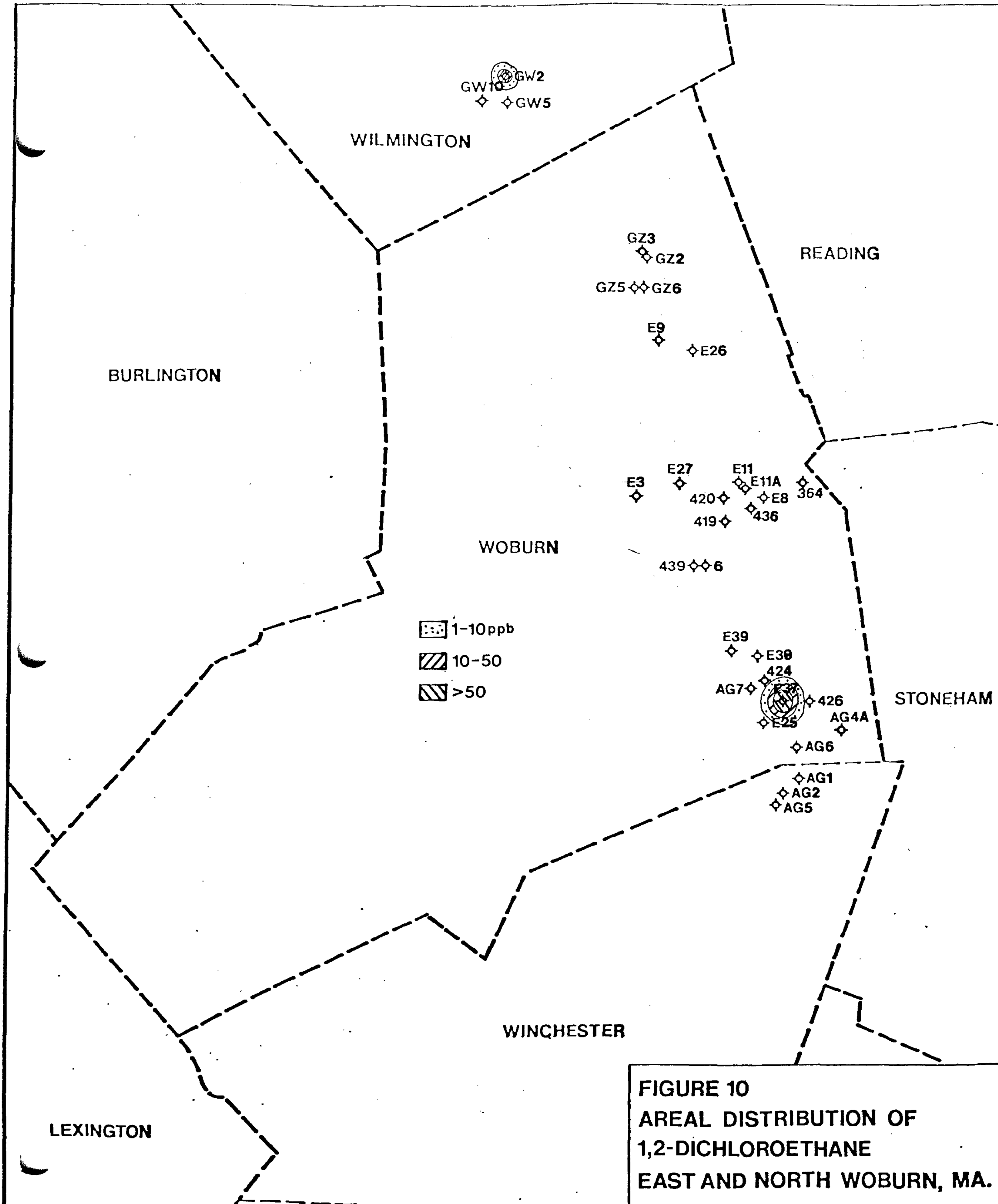


FIGURE 10
AREAL DISTRIBUTION OF 1,2-DICHLOROETHANE EAST AND NORTH WOBURN, MA.

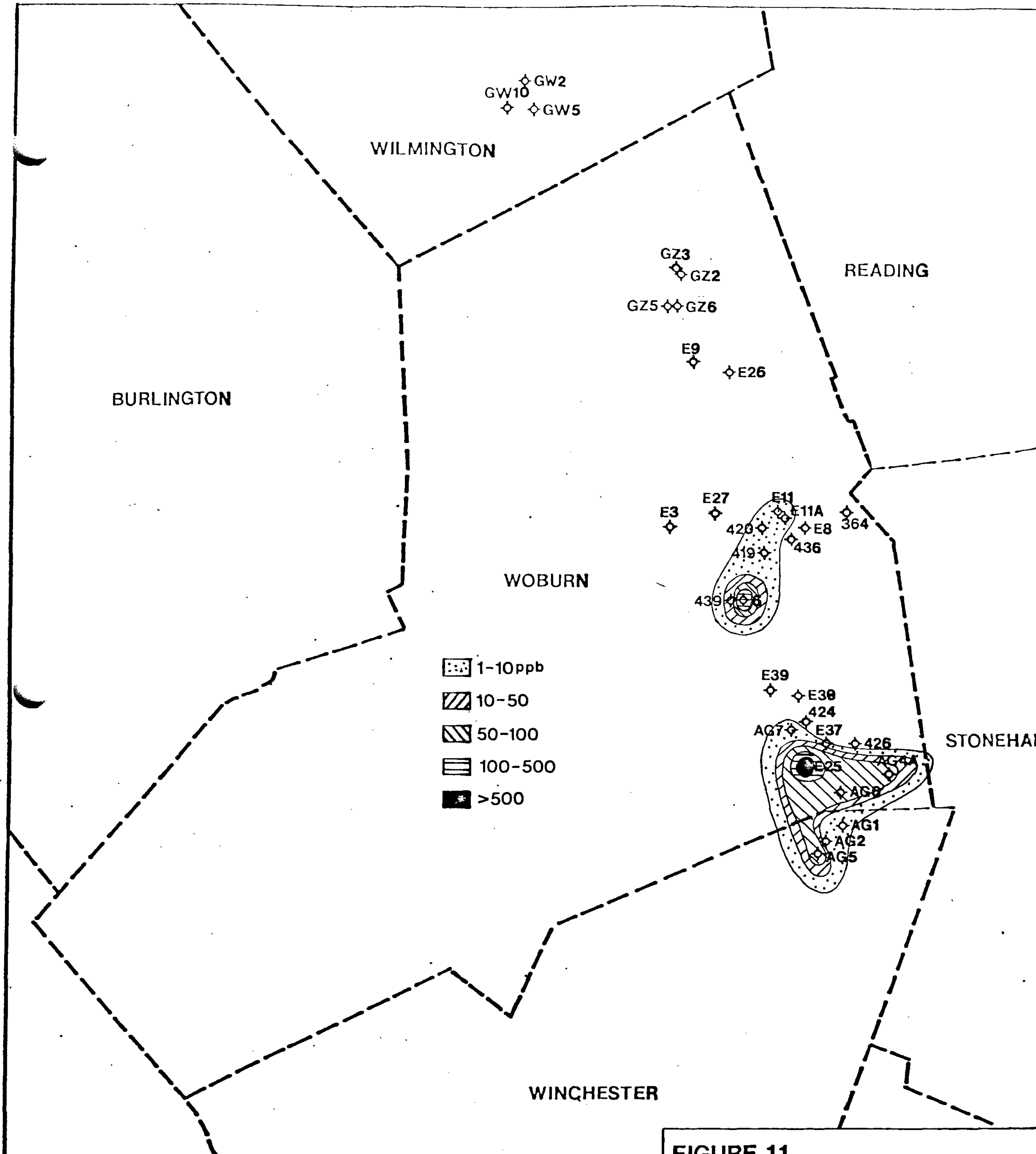


FIGURE 11
AREAL DISTRIBUTION OF 1,1,1-TRICHLOROETHANE EAST AND NORTH WOBURN, MA

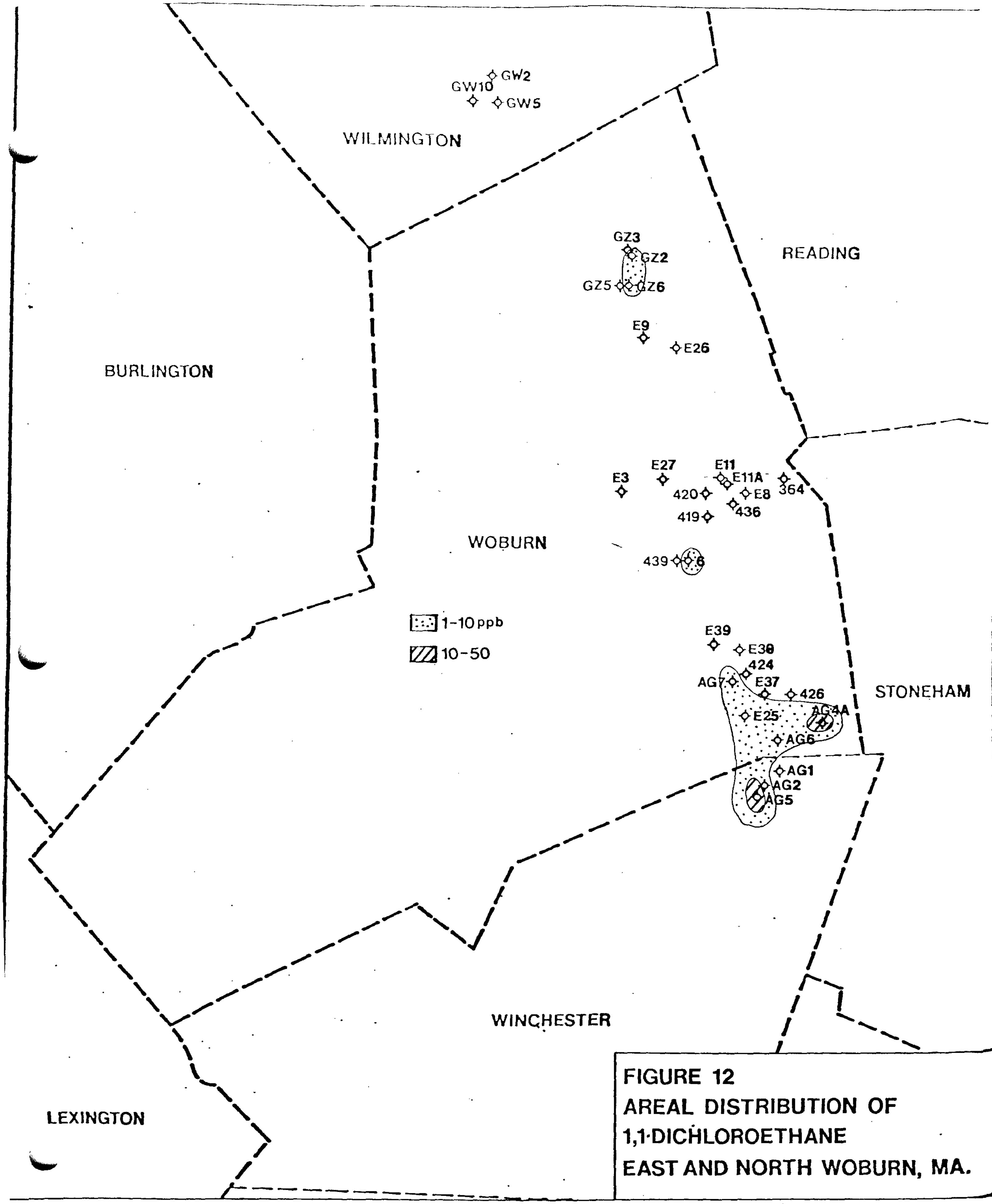


FIGURE 12
AREAL DISTRIBUTION OF 1,1-DICHLOROETHANE EAST AND NORTH WOBURN, MA.

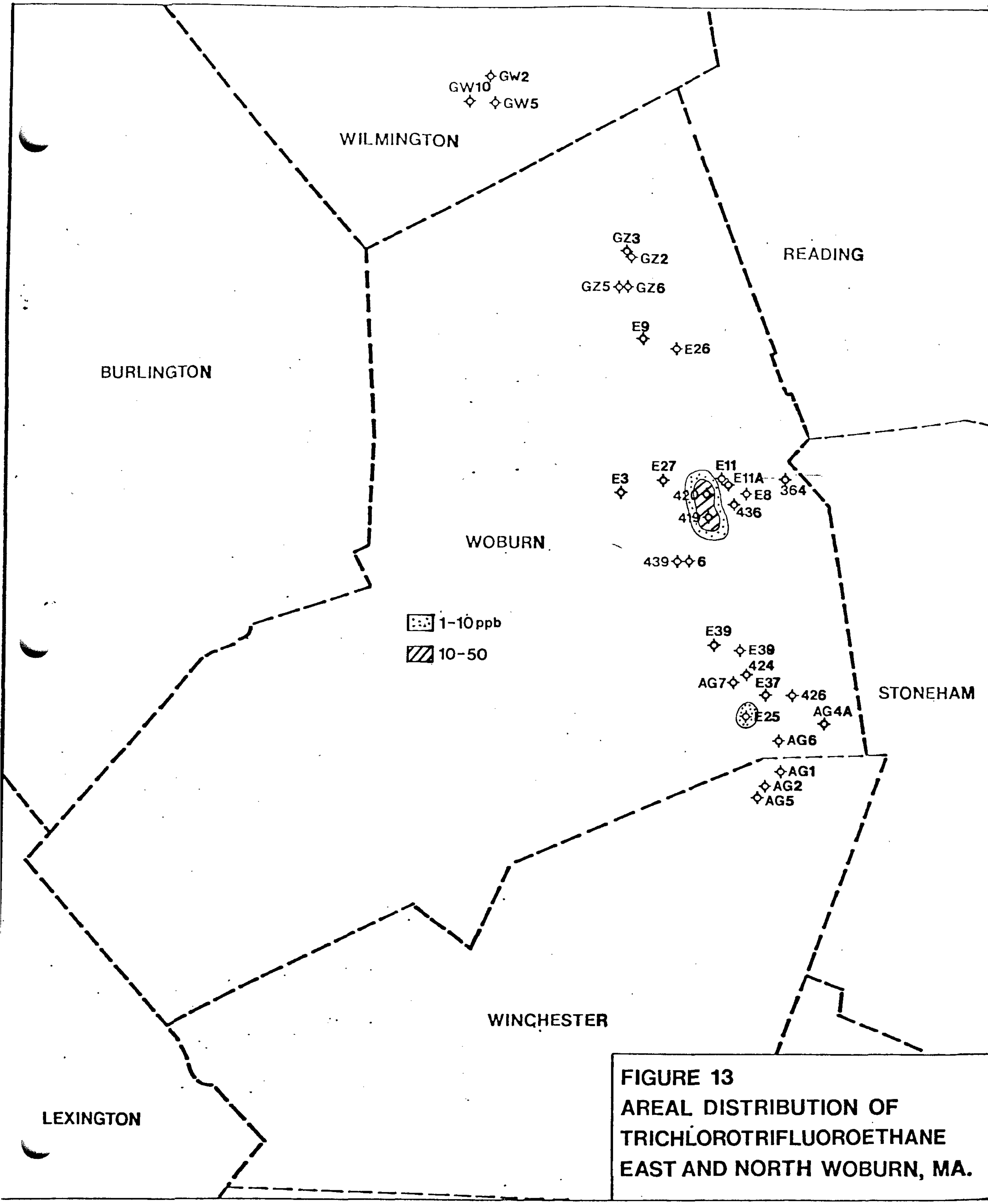


FIGURE 13
AREAL DISTRIBUTION OF TRICHLOROTRIFLUOROETHANE EAST AND NORTH WOBURN, MA.

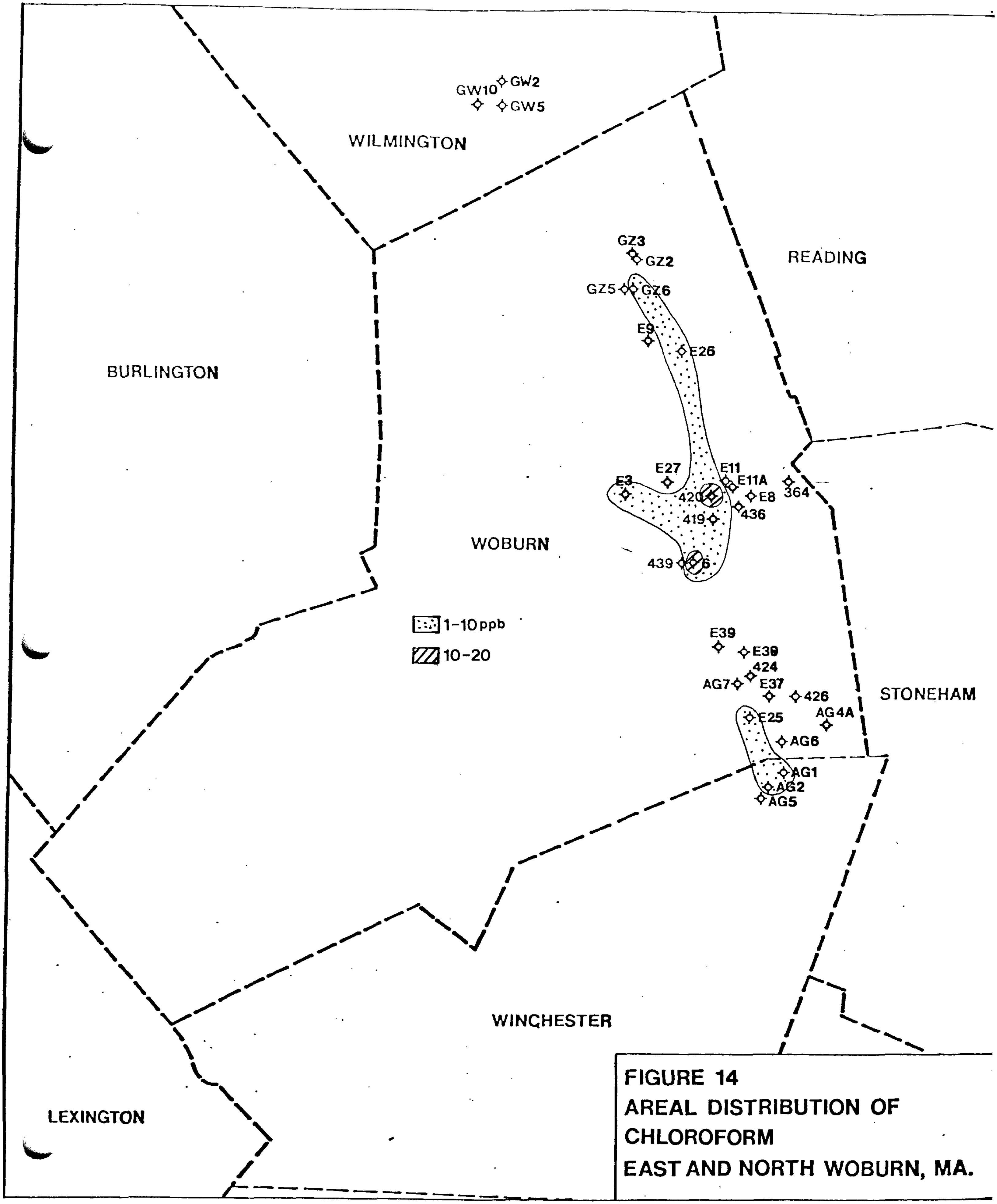


FIGURE 14
AREAL DISTRIBUTION OF
CHLOROFORM
EAST AND NORTH WOBURN, MA.

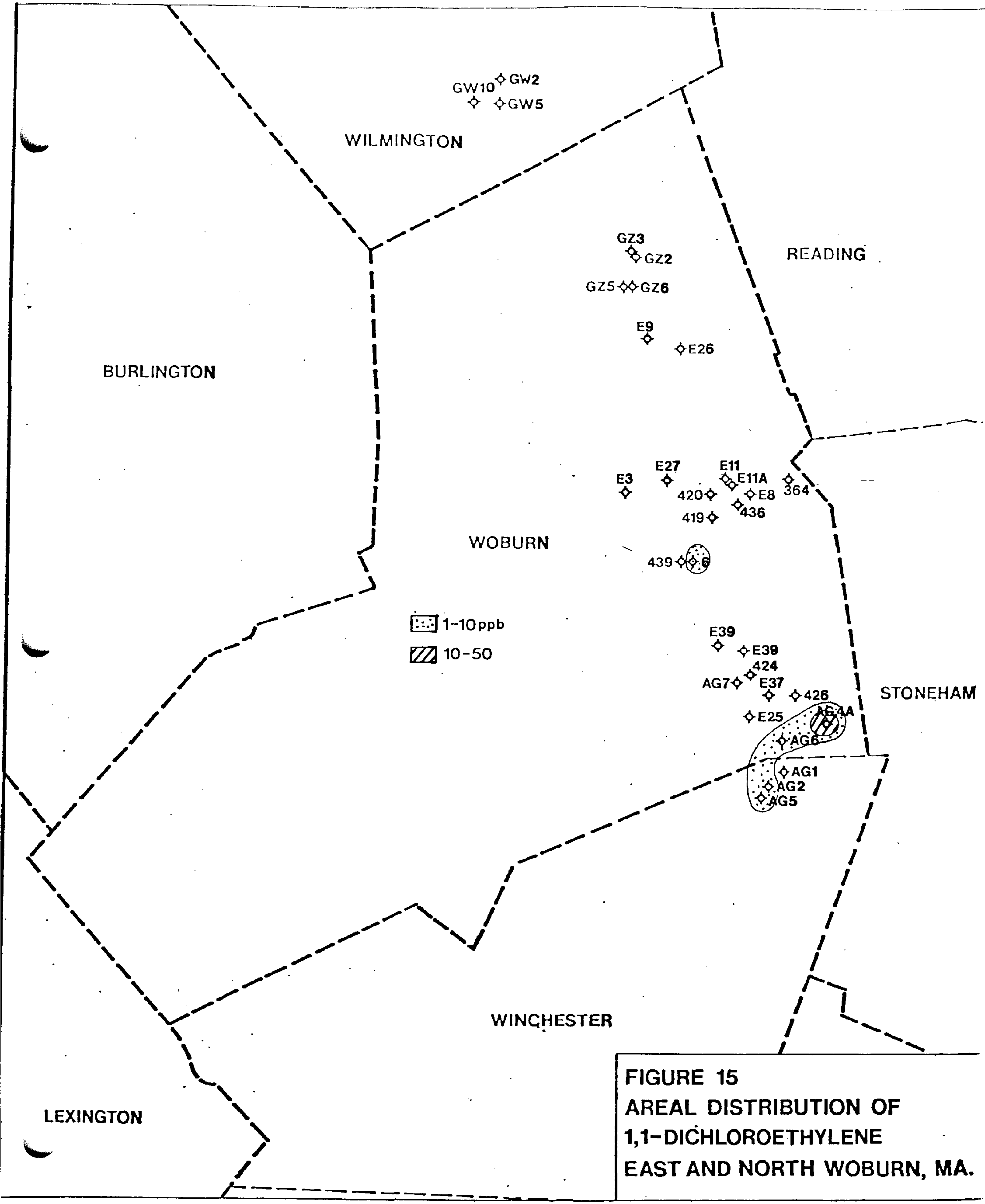


FIGURE 15
AREAL DISTRIBUTION OF
1,1-DICHLOROETHYLENE
EAST AND NORTH WOBURN, MA.

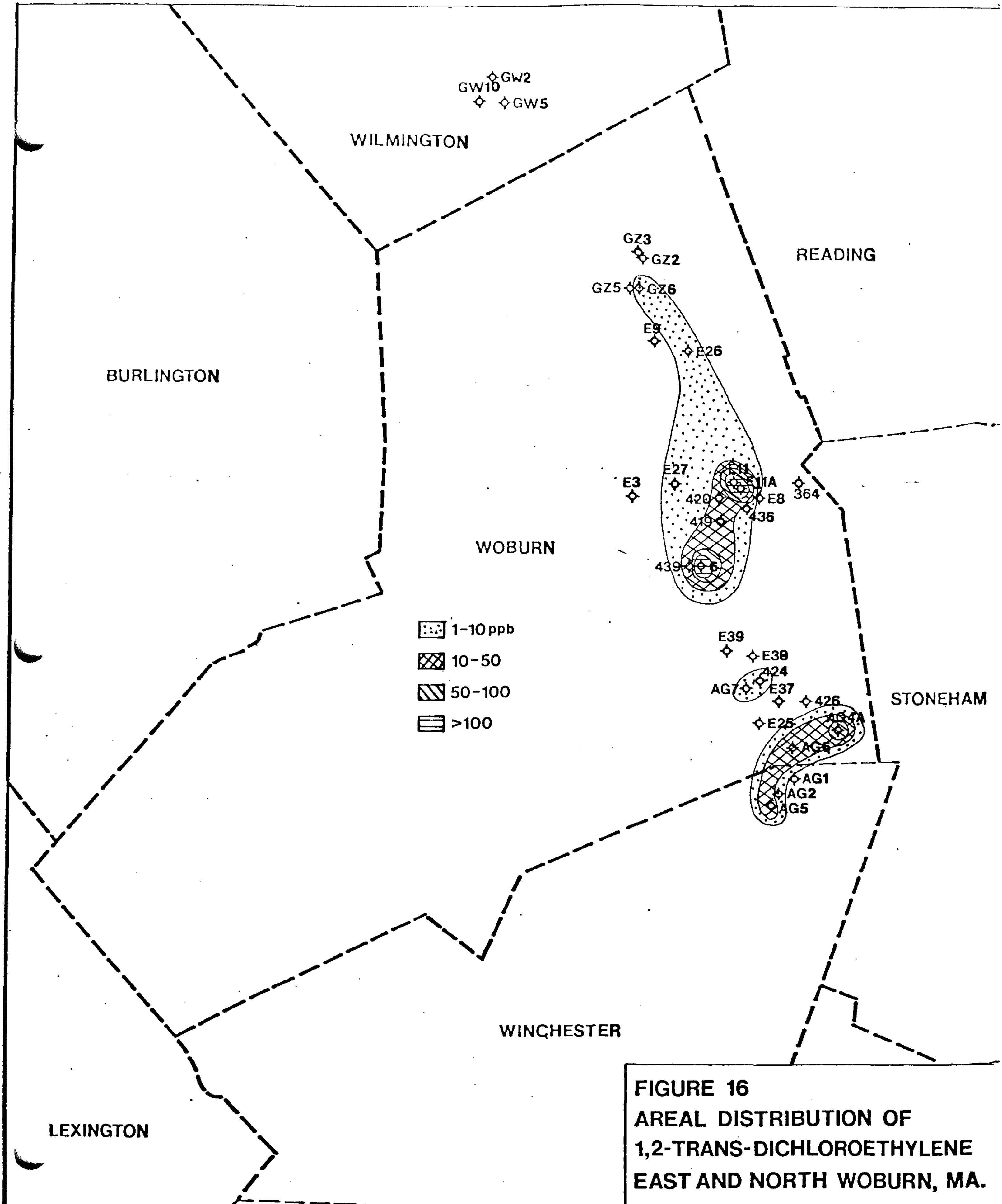
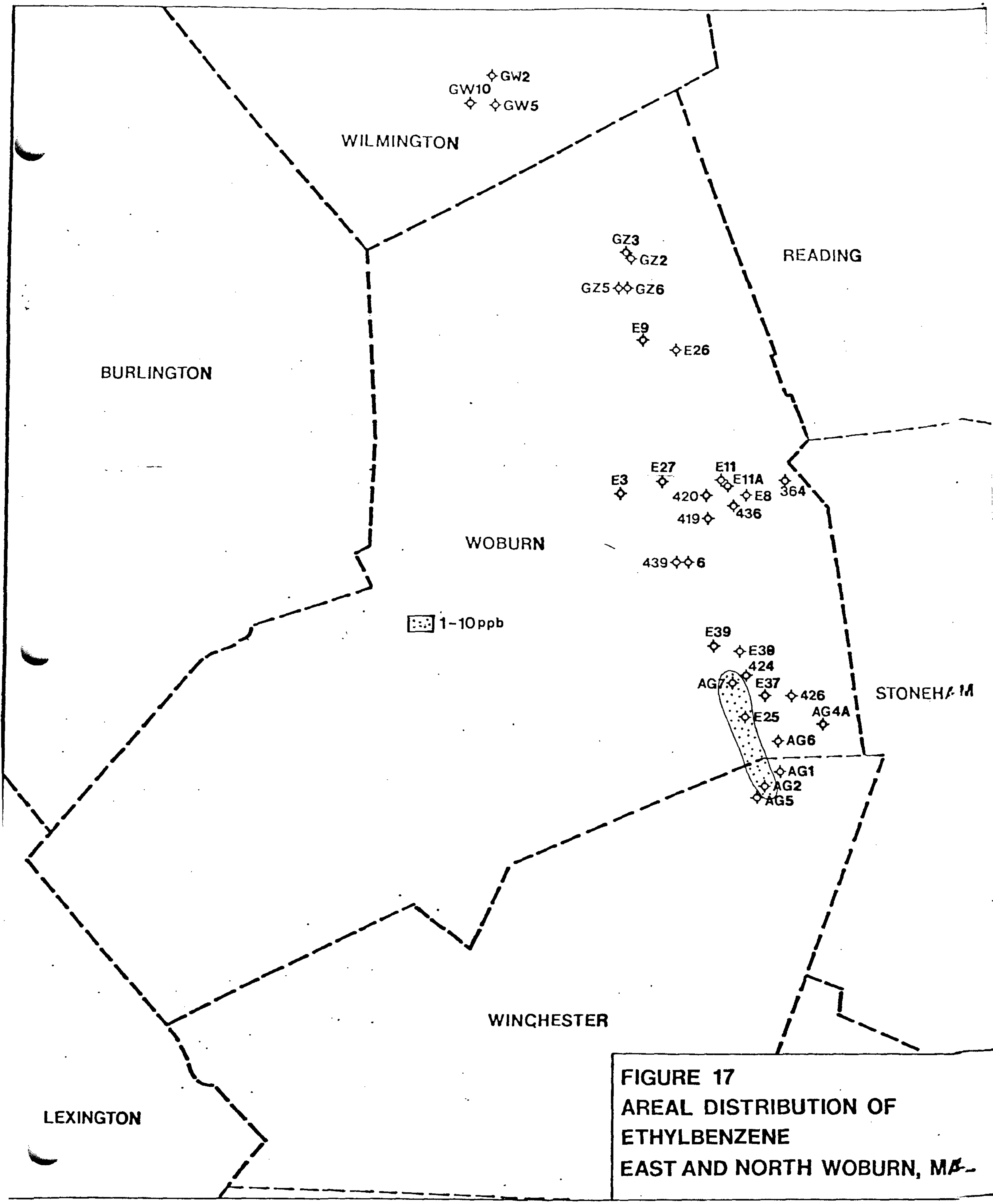


FIGURE 16
AREAL DISTRIBUTION OF 1,2-TRANS-DICHLOROETHYLENE EAST AND NORTH WOBURN, MA.


GW2
GW10
GW5
WILMINGTON
GZ3
GZ2
READING
GZ5
GZ6
E9
E26
BURLINGTON
E27
E11
E11A
E3
420
E8
364
419
436
WOBURN
439
6
1-10ppb
E39
E38
424
AG7
E37
426
STONEHAM
E25
AG4A
AG6
AG1
AG2
AG5
WINCHESTER
LEXINGTON
FIGURE 17
AREAL DISTRIBUTION OF
ETHYLBENZENE
EAST AND NORTH WOBURN, MA

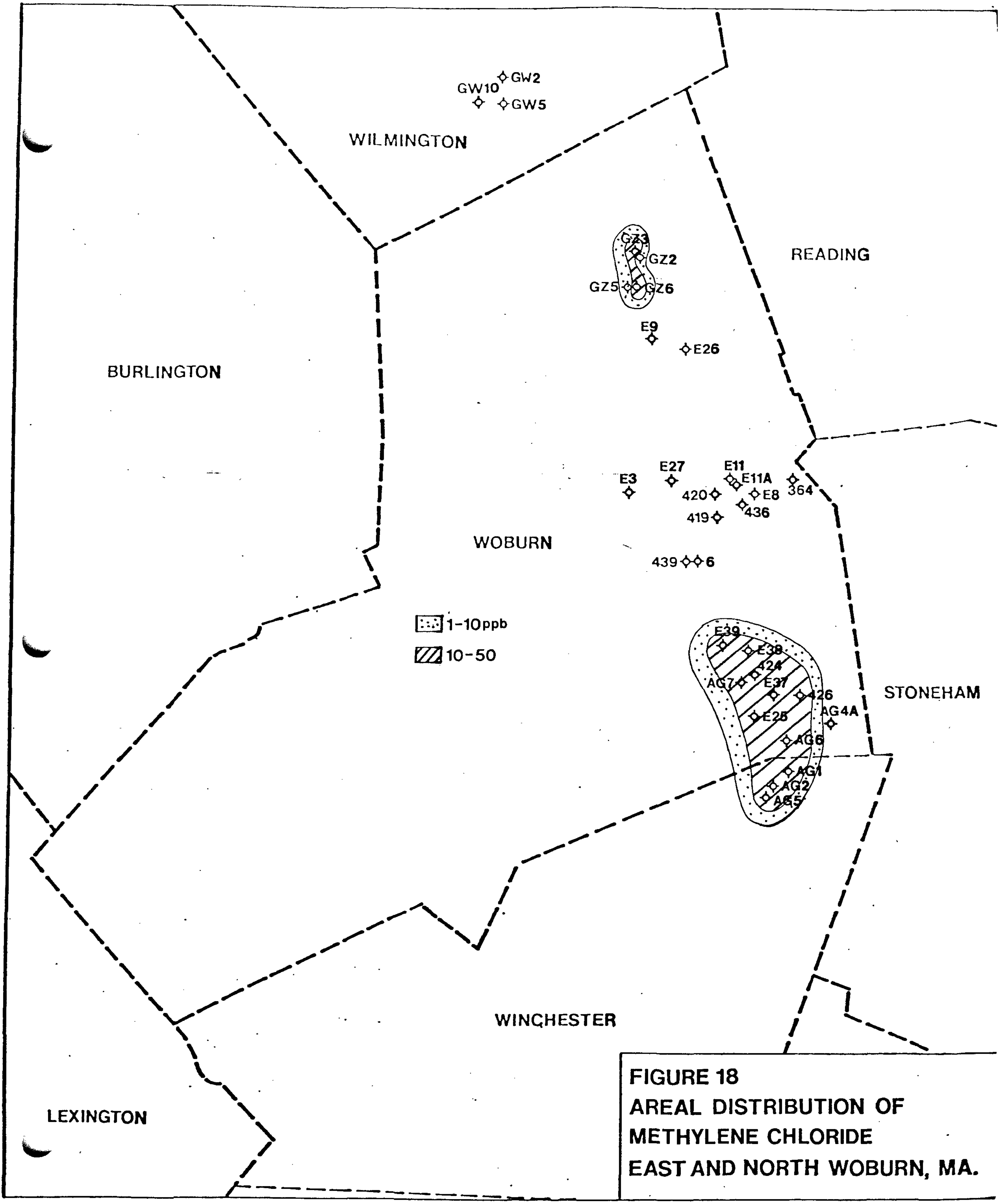


FIGURE 18
AREAL DISTRIBUTION OF METHYLENE CHLORIDE EAST AND NORTH WOBURN, MA.

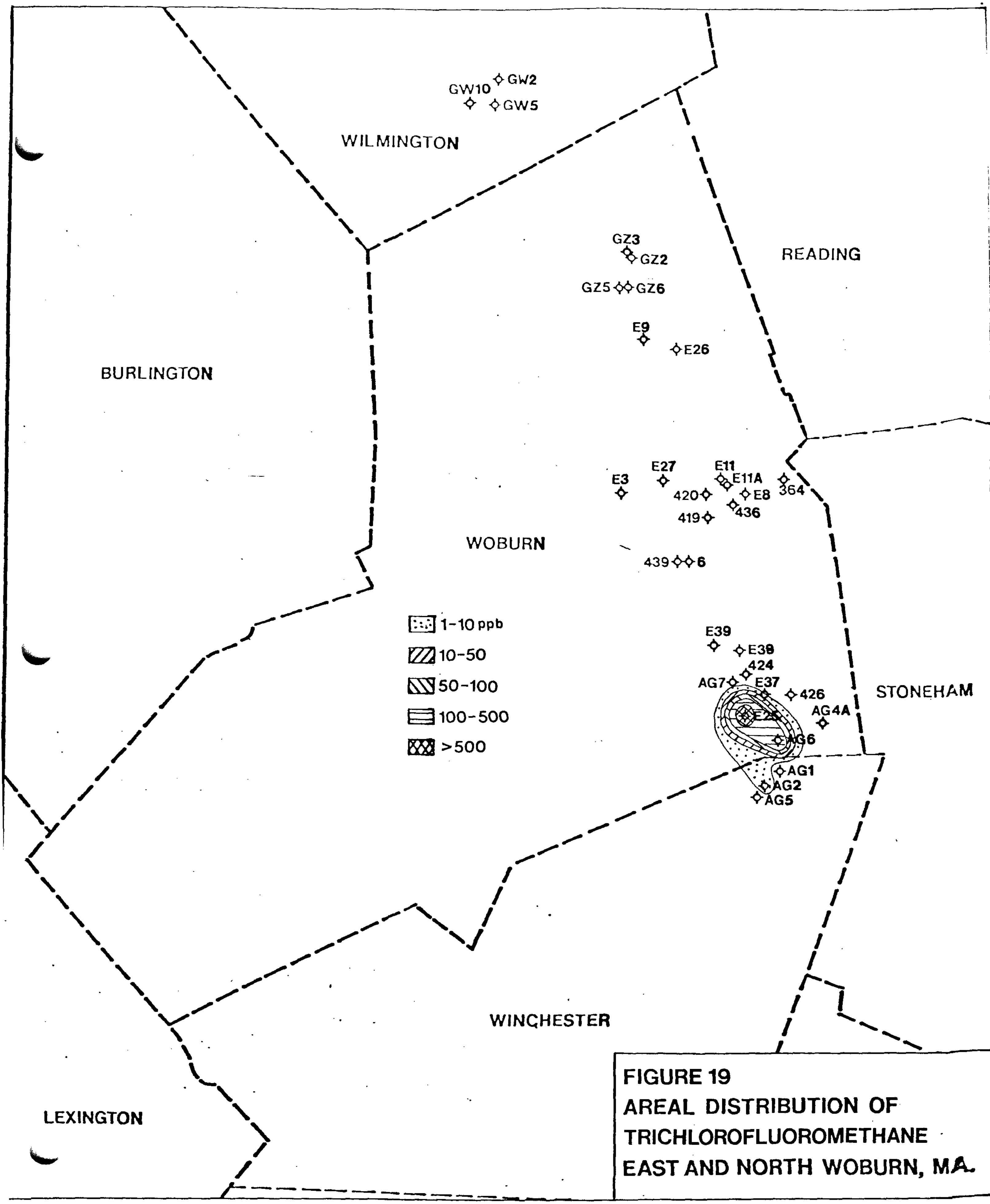


FIGURE 19
AREAL DISTRIBUTION OF TRICHLOROFLUOROMETHANE EAST AND NORTH WOBURN, MA.

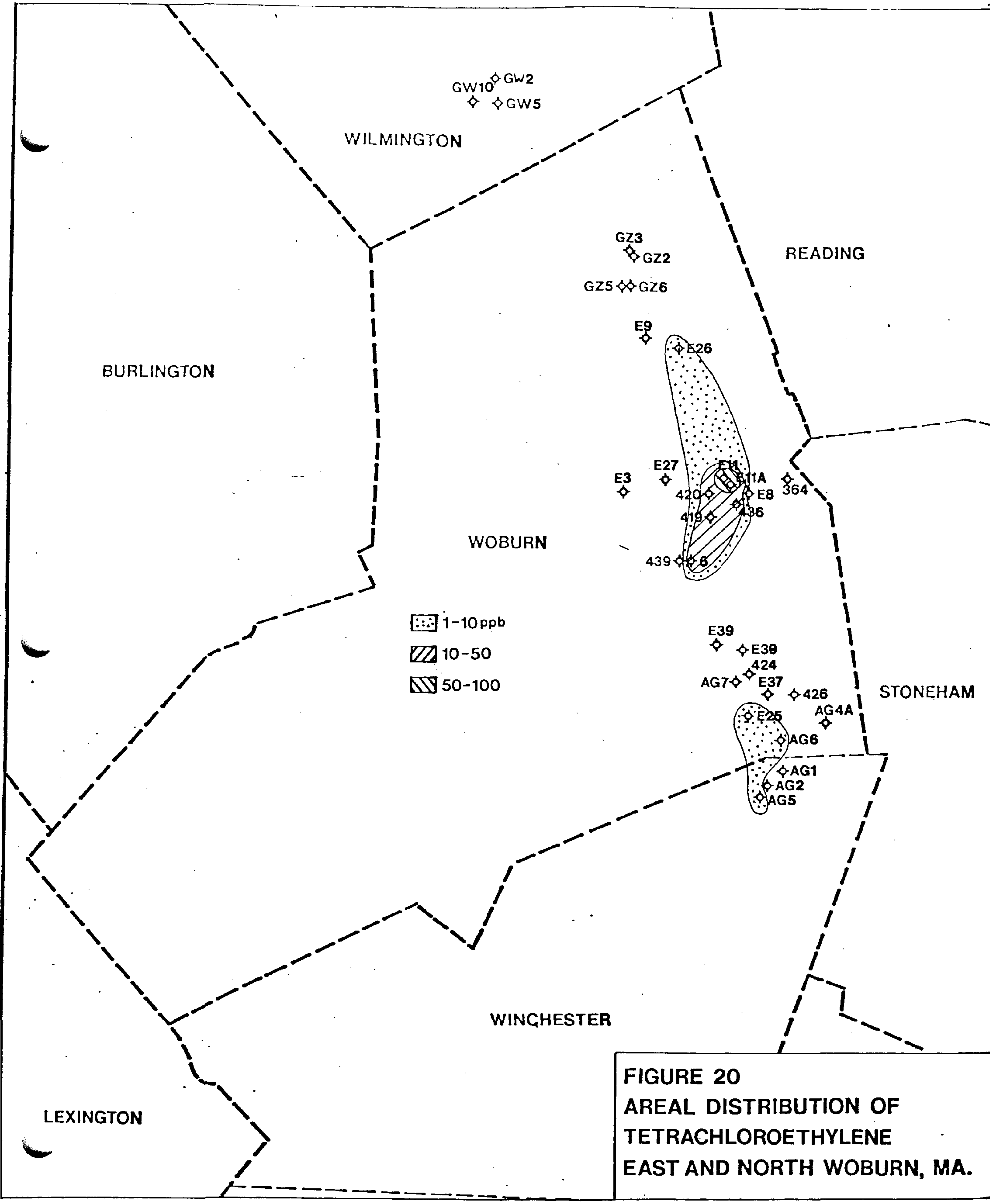


FIGURE 20
AREAL DISTRIBUTION OF
TETRACHLOROETHYLENE
EAST AND NORTH WOBURN, MA.

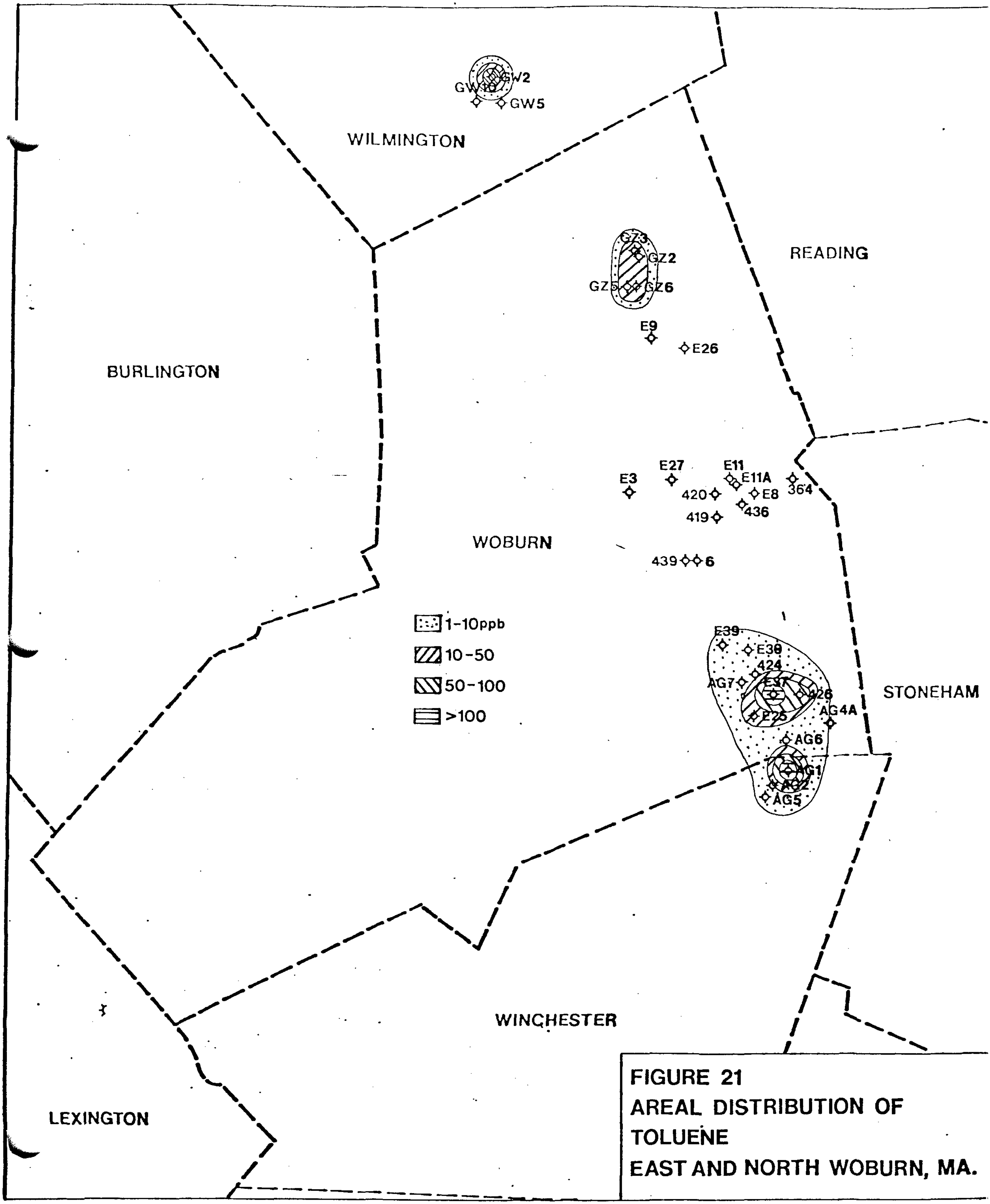


FIGURE 21
AREAL DISTRIBUTION OF TOLUENE
EAST AND NORTH WOBURN, MA.

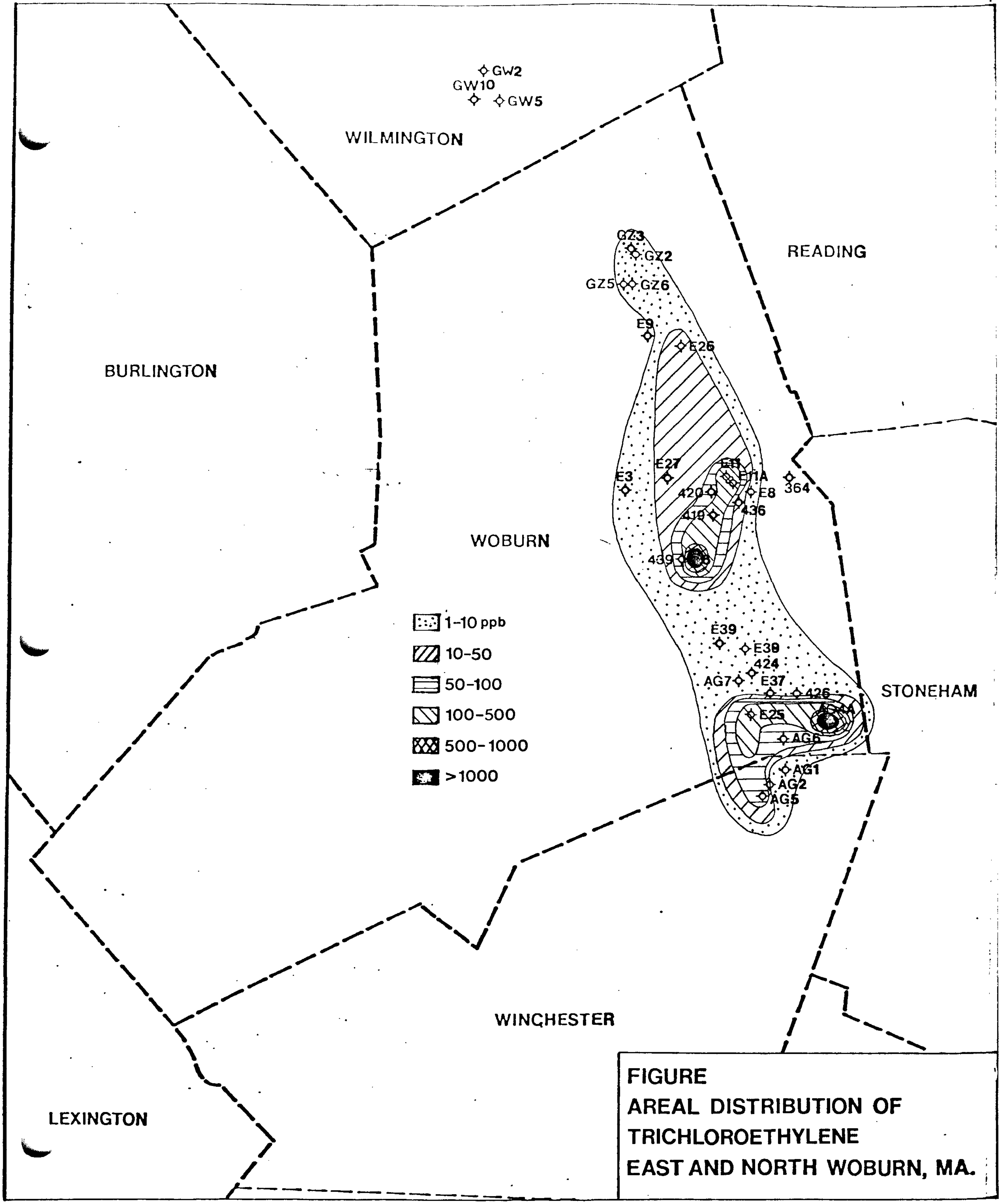


FIGURE
AREAL DISTRIBUTION OF TRICHLOROETHYLENE EAST AND NORTH WOBURN, MA.

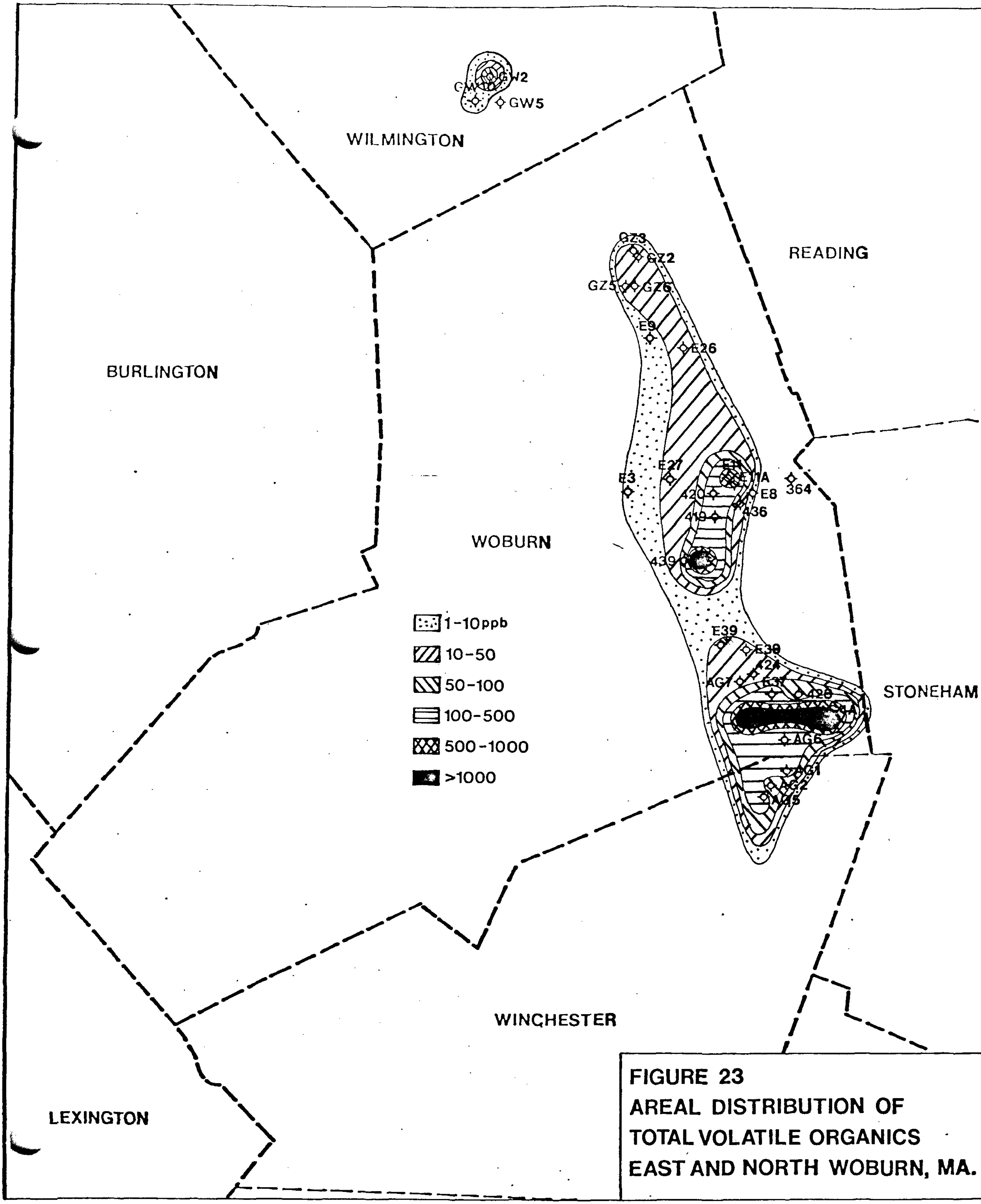


FIGURE 23
AREAL DISTRIBUTION OF TOTAL VOLATILE ORGANICS EAST AND NORTH WOBURN, MA.

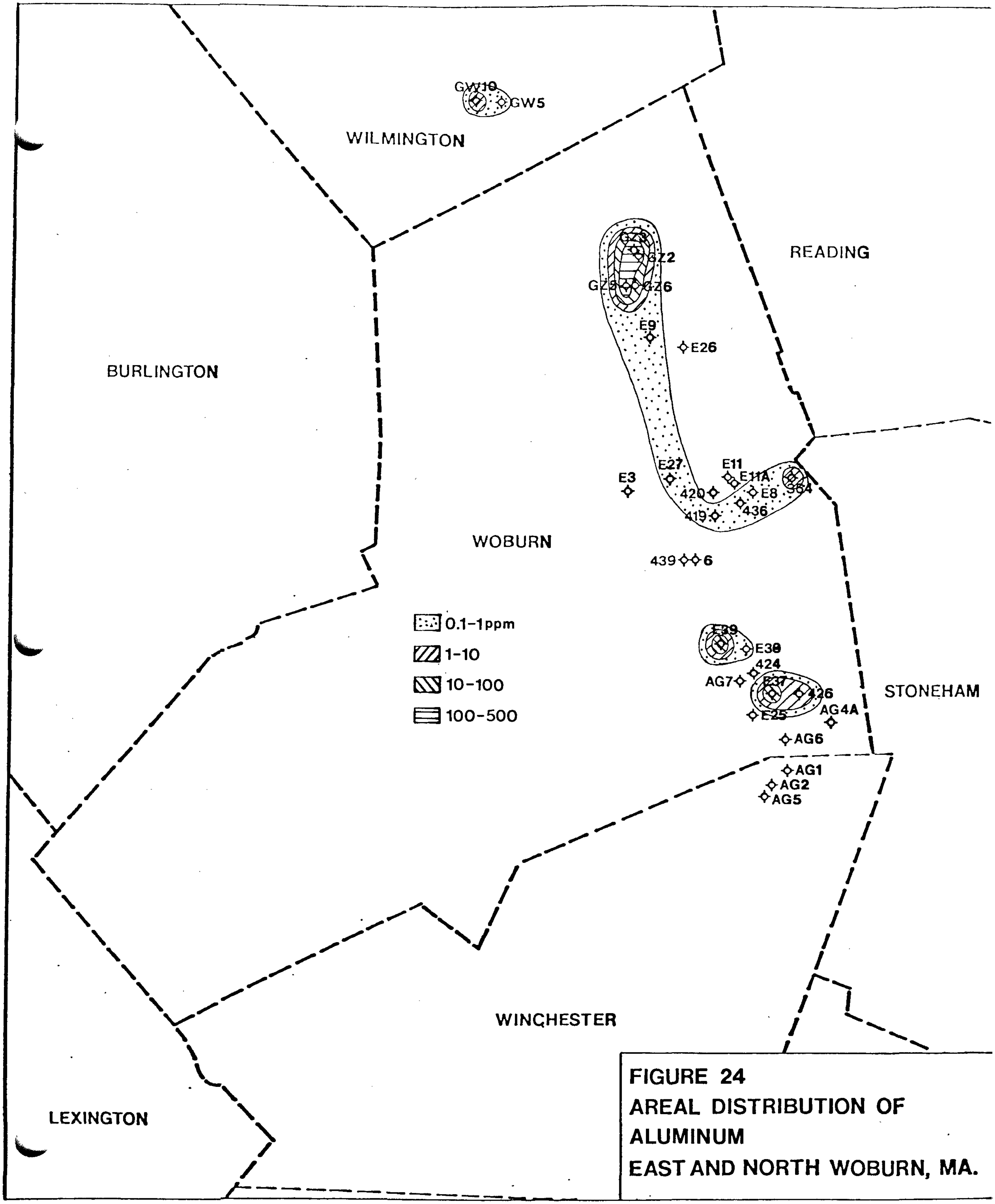


FIGURE 24
AREAL DISTRIBUTION OF ALUMINUM
EAST AND NORTH WOBURN, MA.

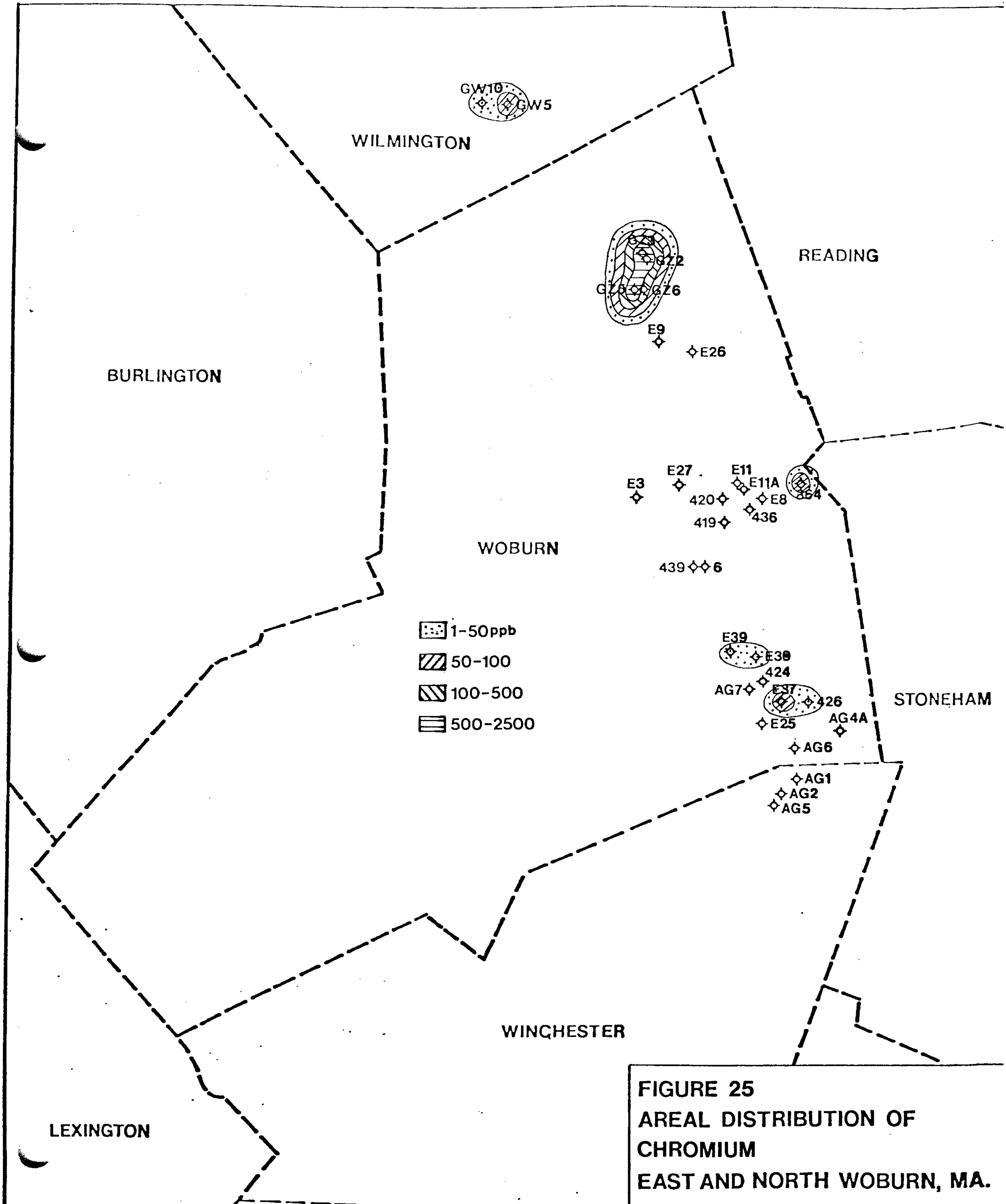


FIGURE 25
AREAL DISTRIBUTION OF CHROMIUM
EAST AND NORTH WOBURN, MA.

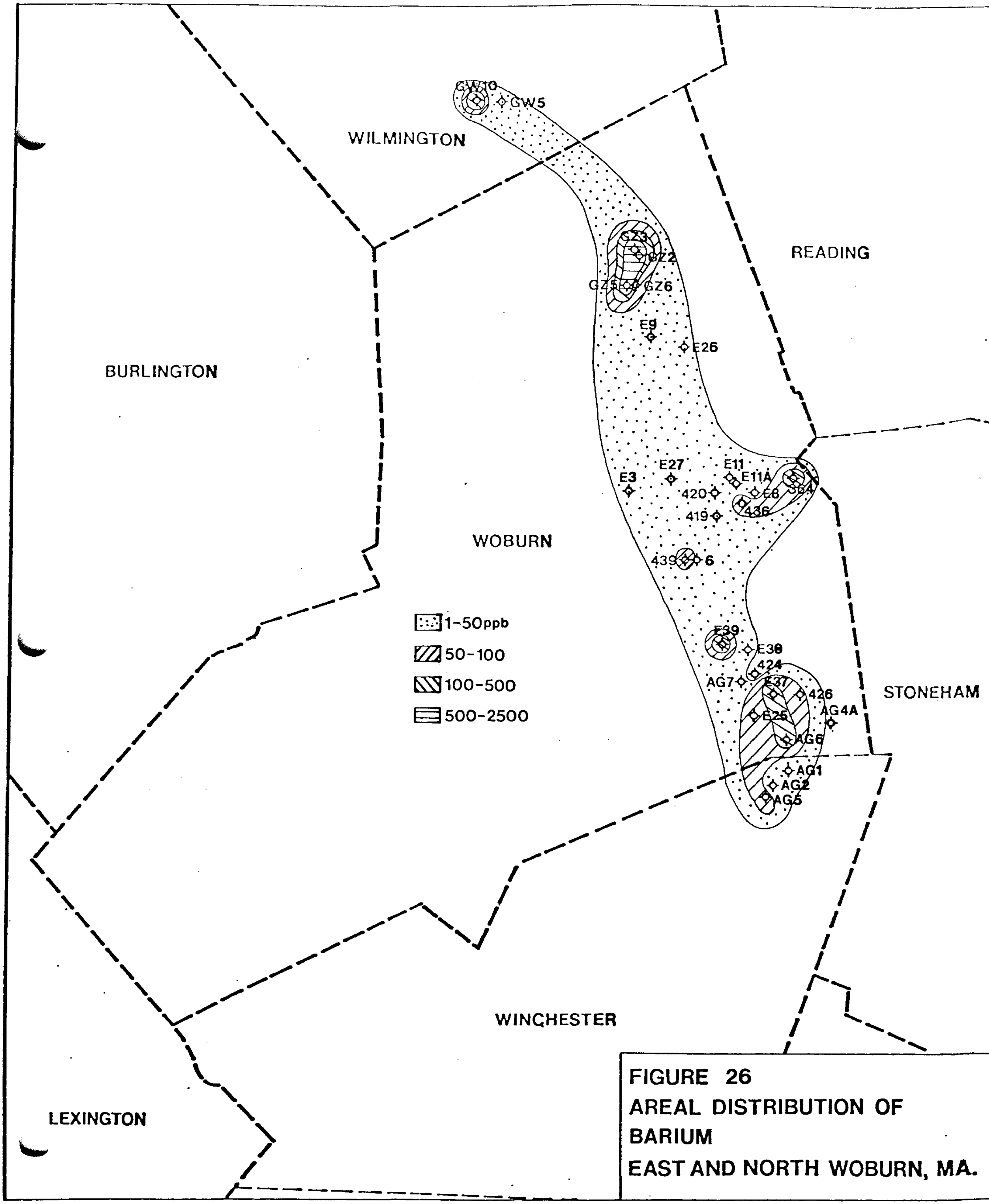


FIGURE 26
AREAL DISTRIBUTION OF BARIUM
EAST AND NORTH WOBURN, MA.

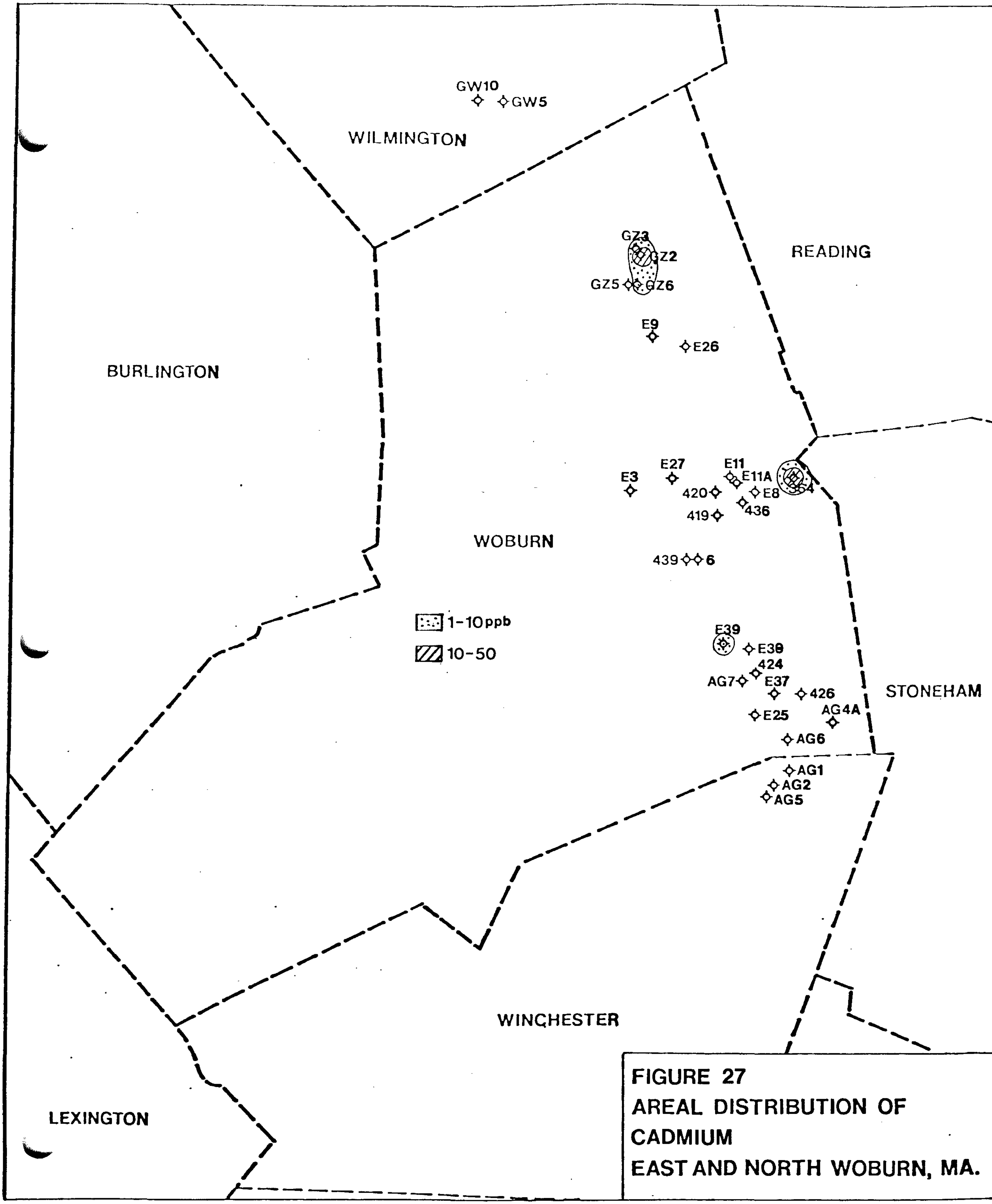


FIGURE 27
AREAL DISTRIBUTION OF CADMIUM
EAST AND NORTH WOBURN, MA.

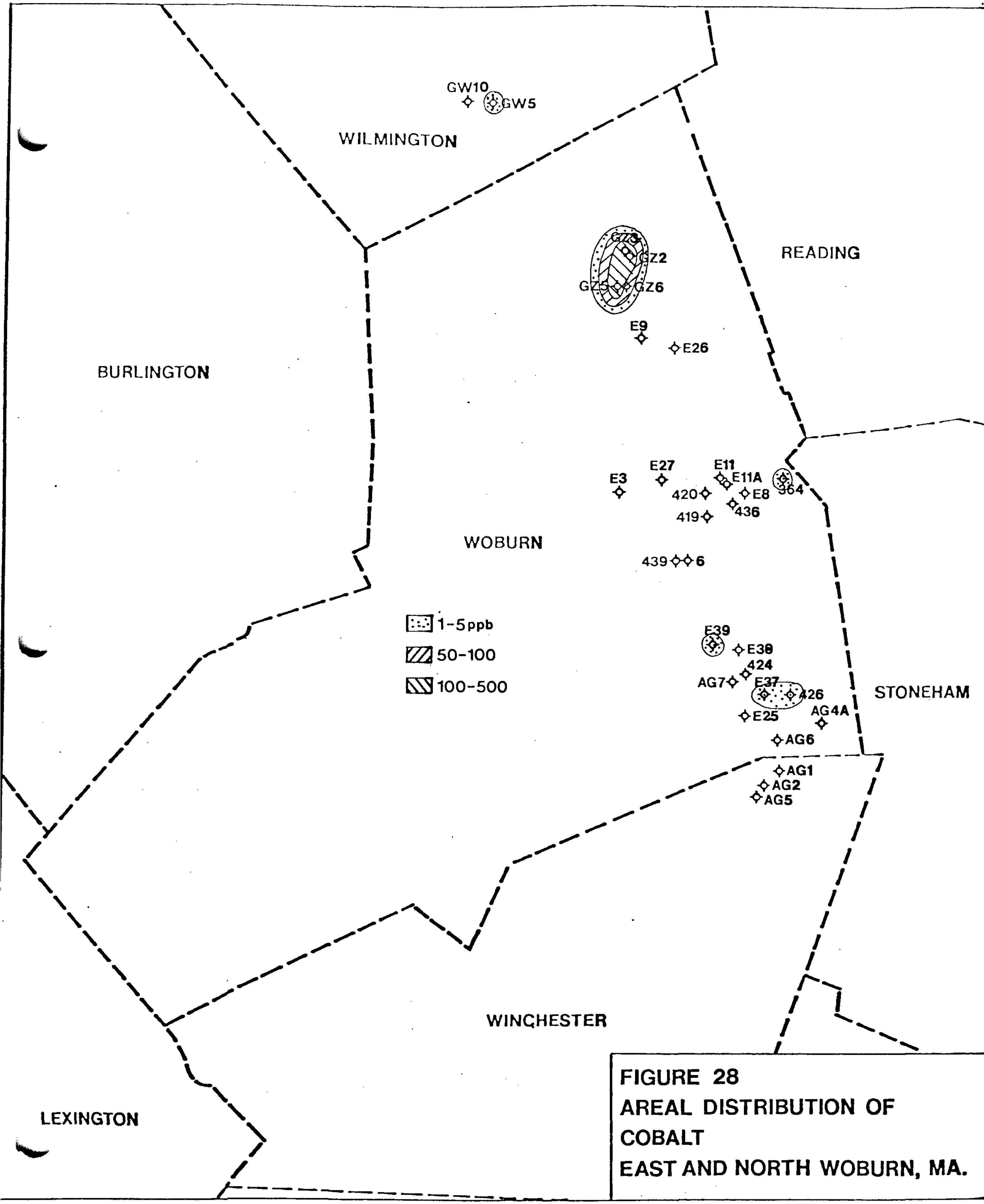


FIGURE 28
AREAL DISTRIBUTION OF COBALT
EAST AND NORTH WOBURN, MA.

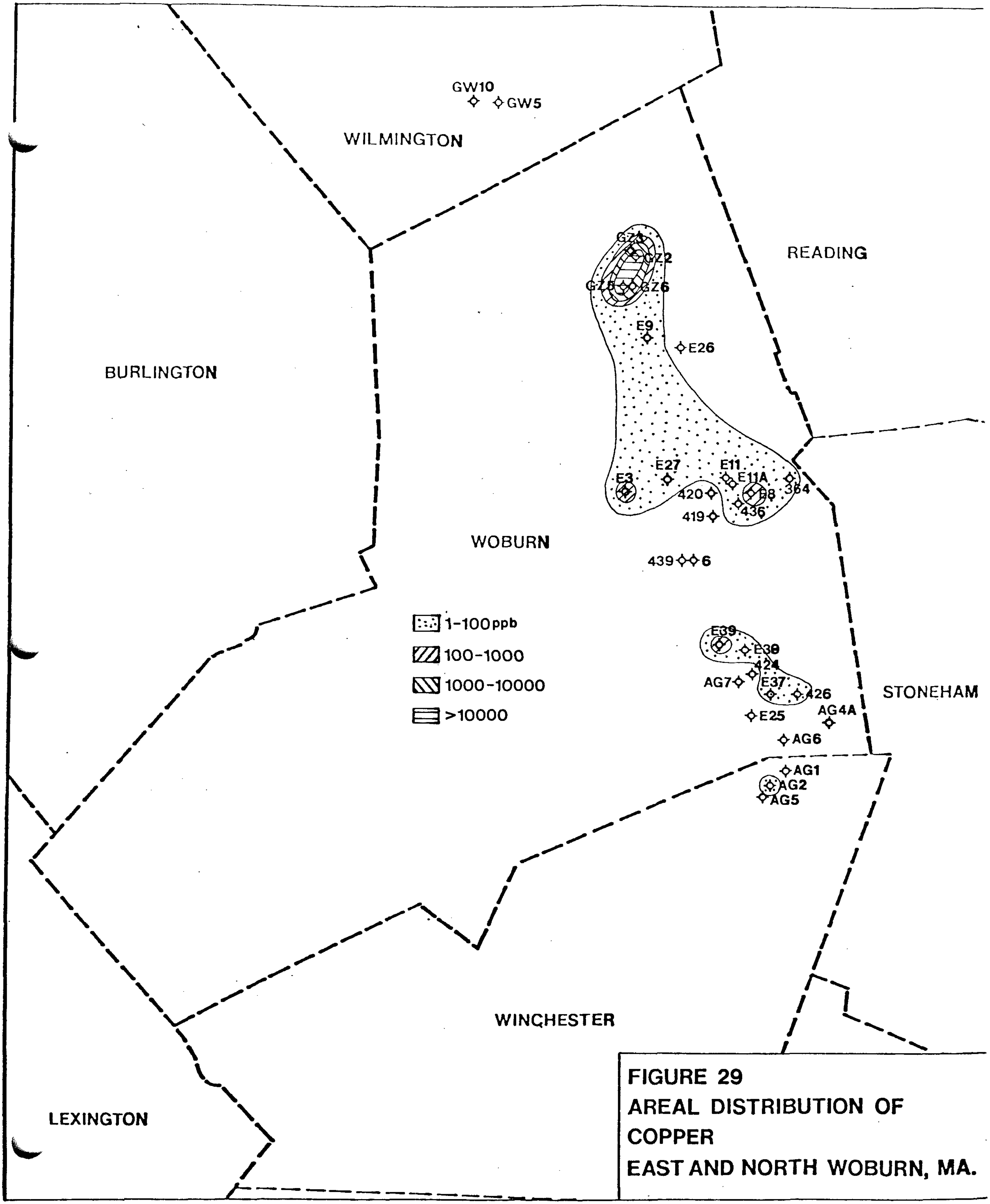


FIGURE 29
AREAL DISTRIBUTION OF COPPER
EAST AND NORTH WOBURN, MA.

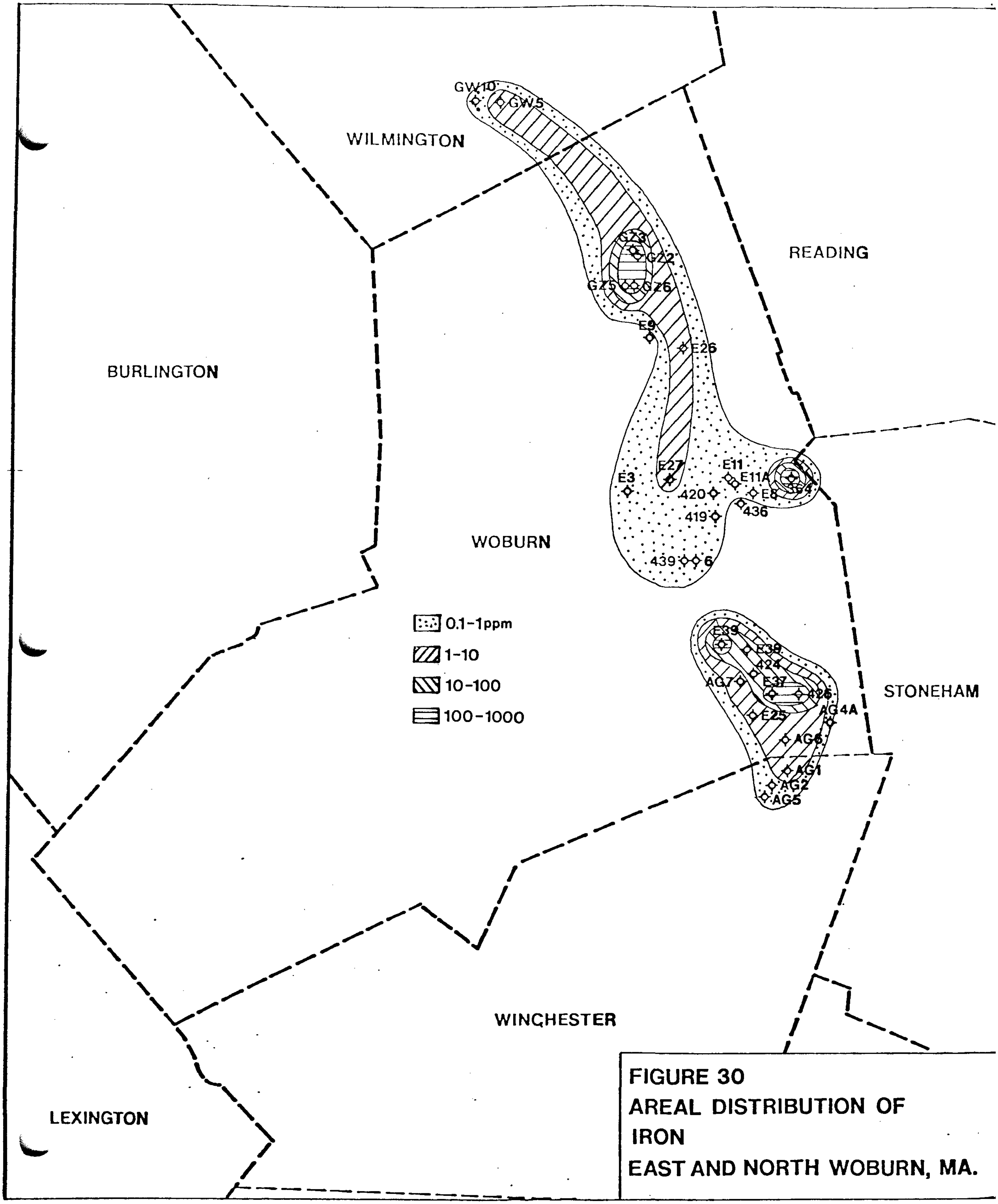


FIGURE 30
AREAL DISTRIBUTION OF
IRON
EAST AND NORTH WOBURN, MA.

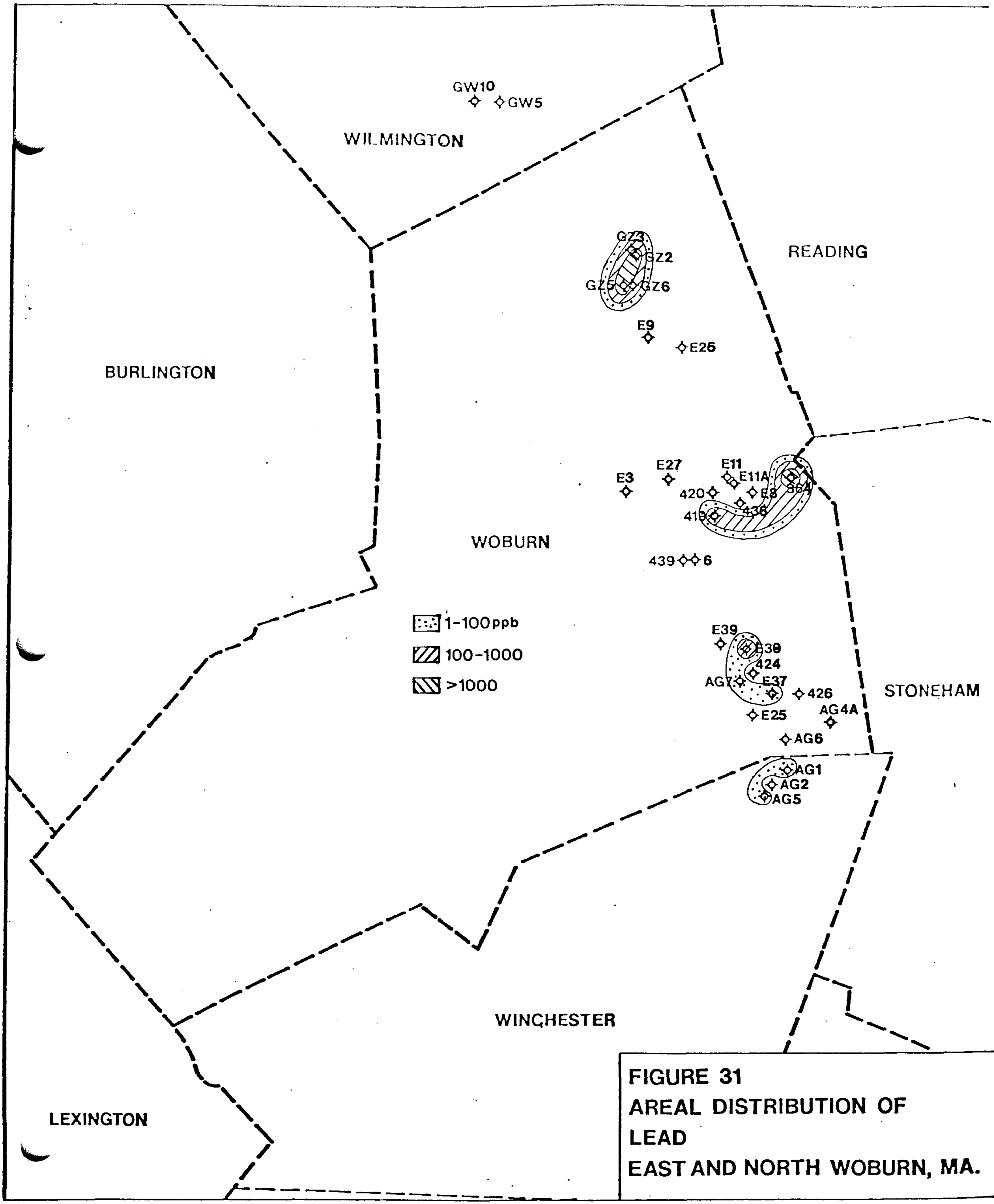


FIGURE 31
AREAL DISTRIBUTION OF LEAD
EAST AND NORTH WOBURN, MA.

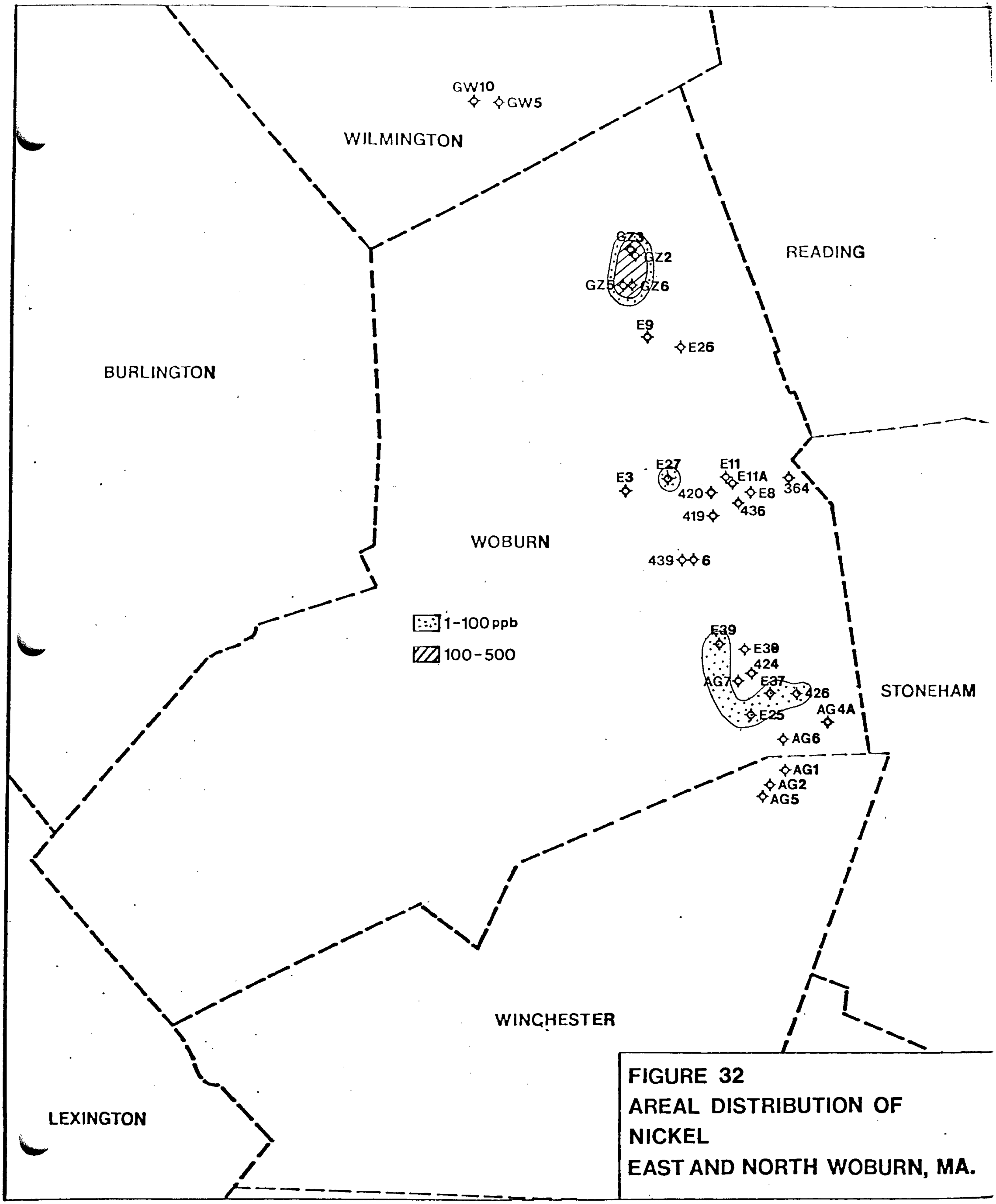


FIGURE 32
AREAL DISTRIBUTION OF NICKEL
EAST AND NORTH WOBURN, MA.

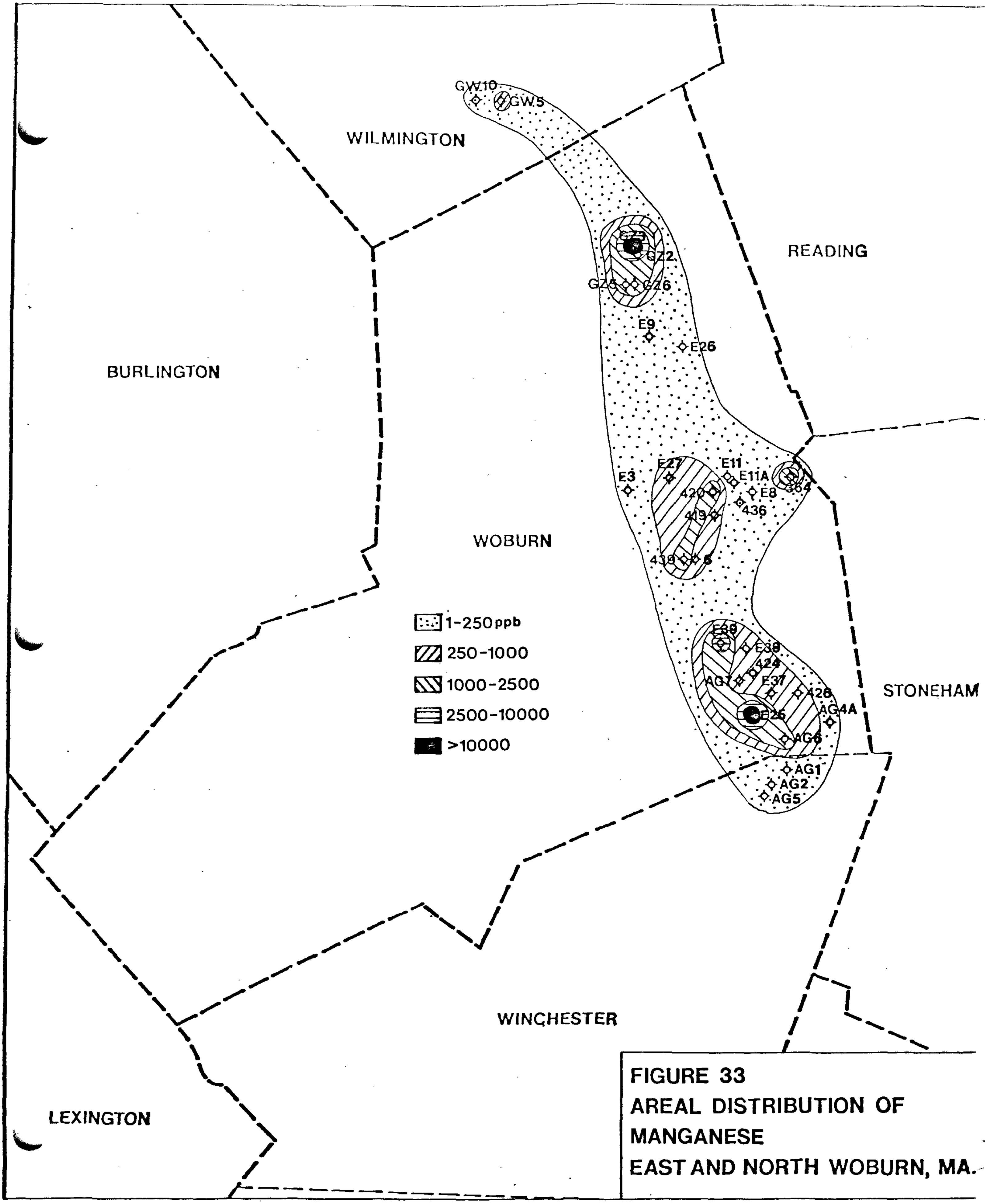


FIGURE 33
AREAL DISTRIBUTION OF MANGANESE
EAST AND NORTH WOBURN, MA.

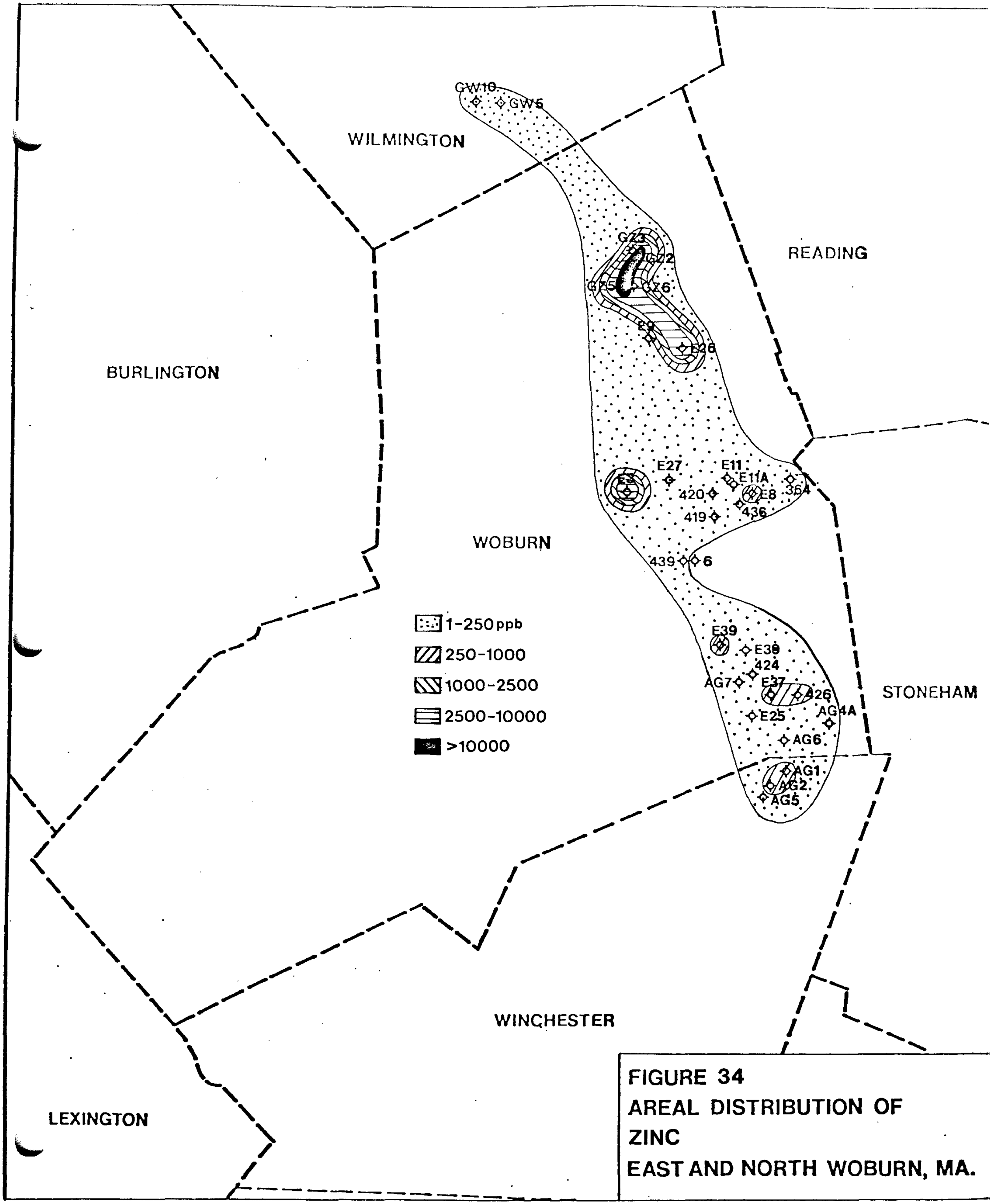


FIGURE 34
AREAL DISTRIBUTION OF ZINC
EAST AND NORTH WOBURN, MA.

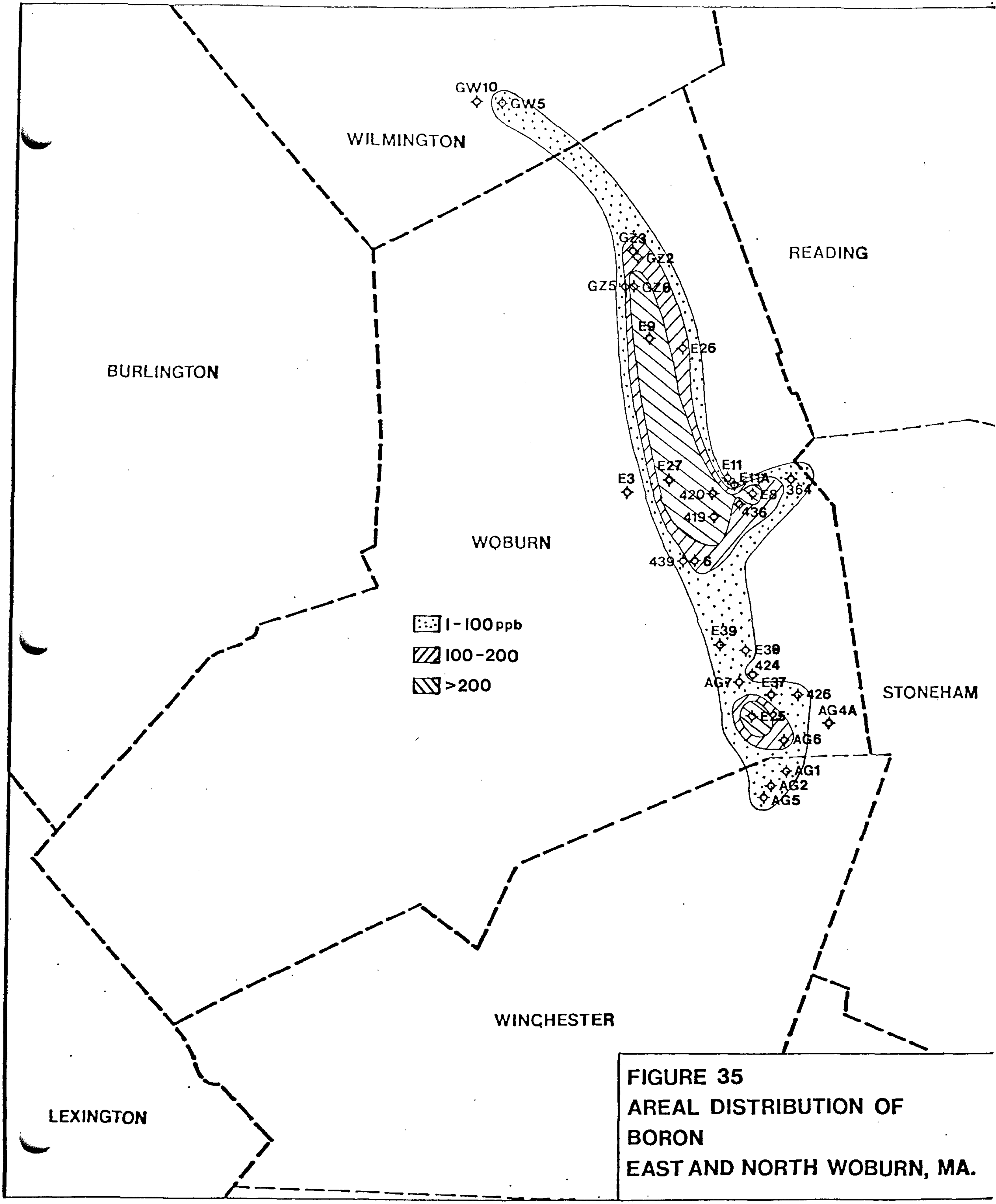


FIGURE 35
AREAL DISTRIBUTION OF BORON
EAST AND NORTH WOBURN, MA.

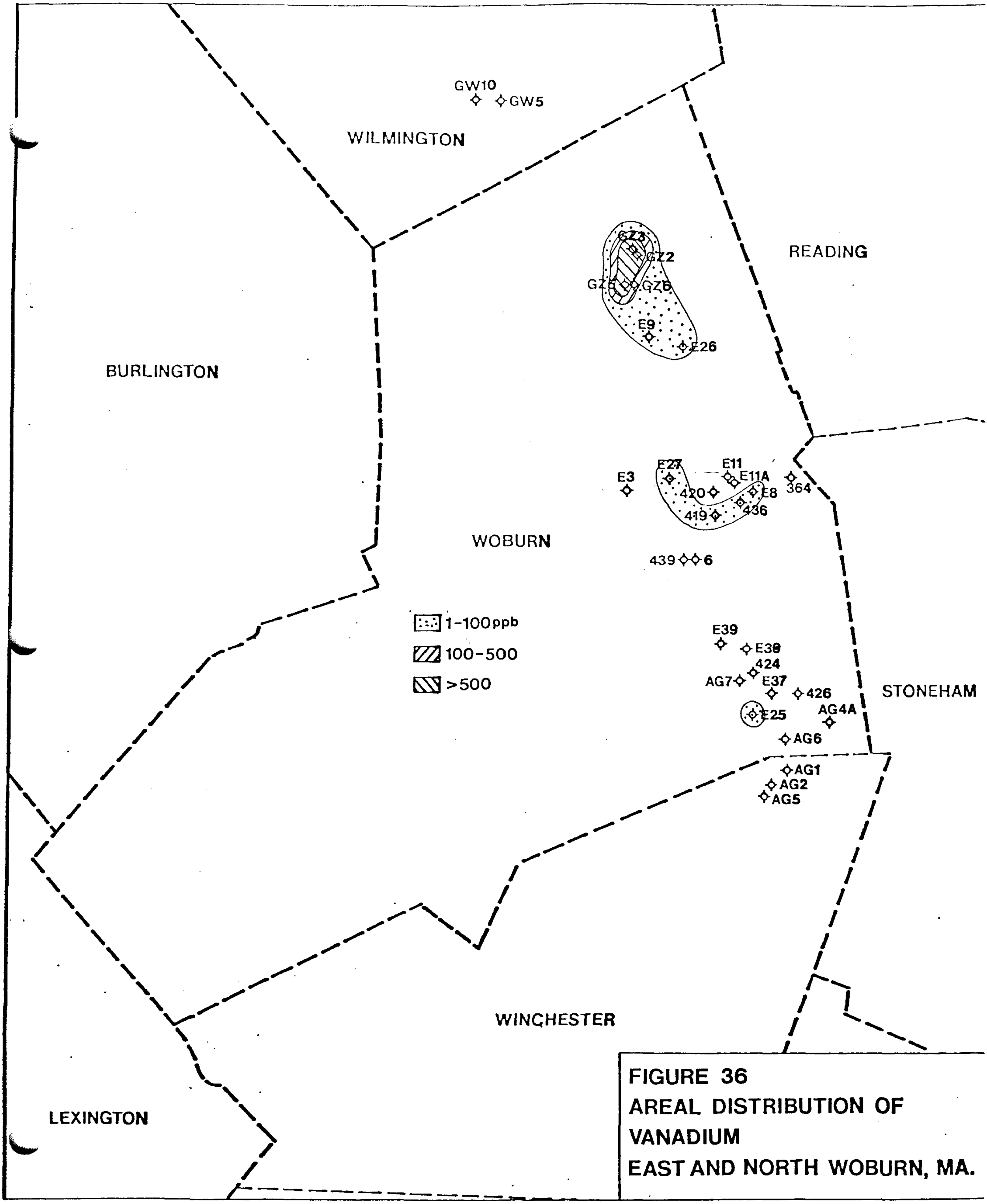


FIGURE 36
AREAL DISTRIBUTION OF VANADIUM
EAST AND NORTH WOBURN, MA.

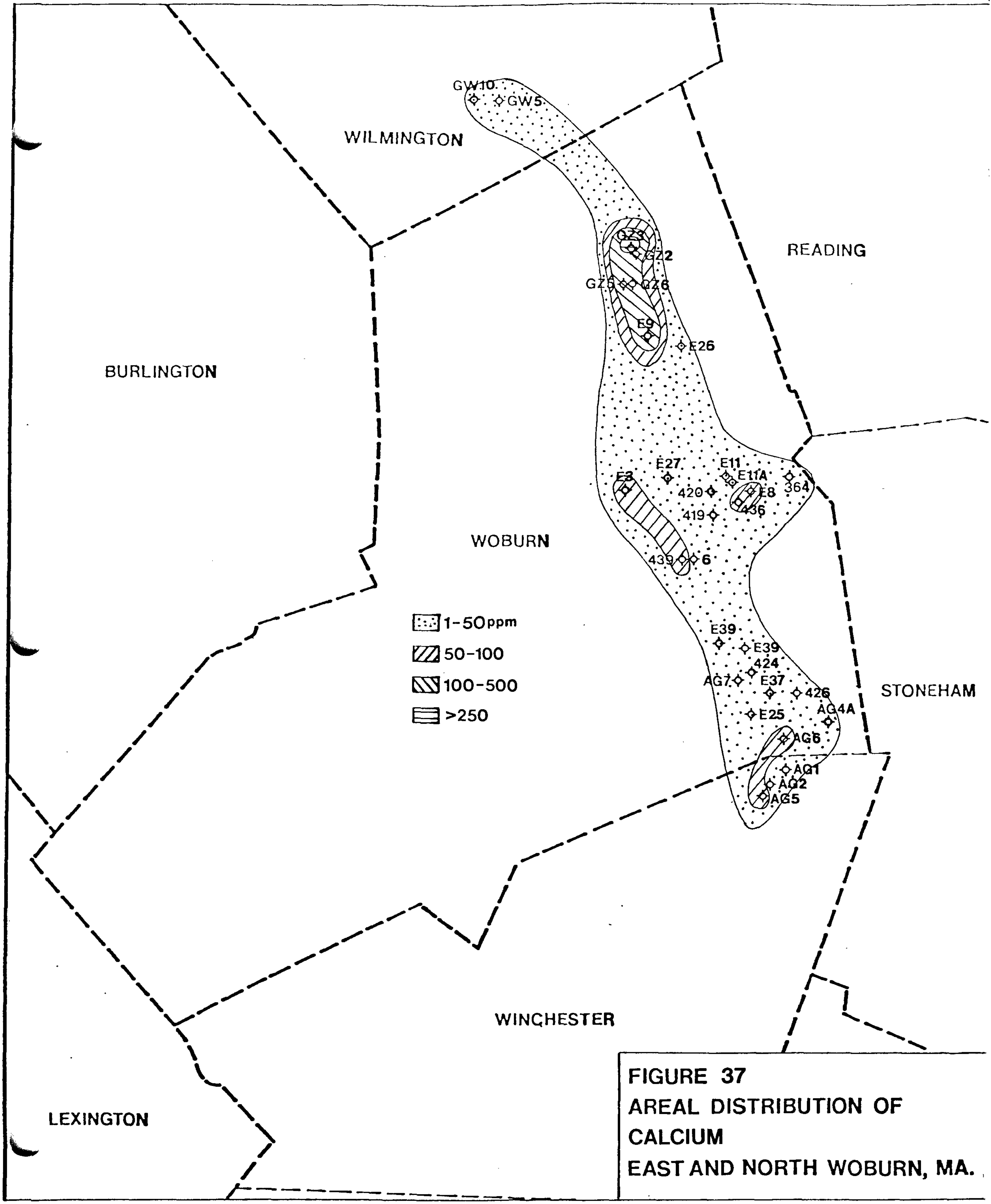


FIGURE 37
AREAL DISTRIBUTION OF CALCIUM
EAST AND NORTH WOBURN, MA.

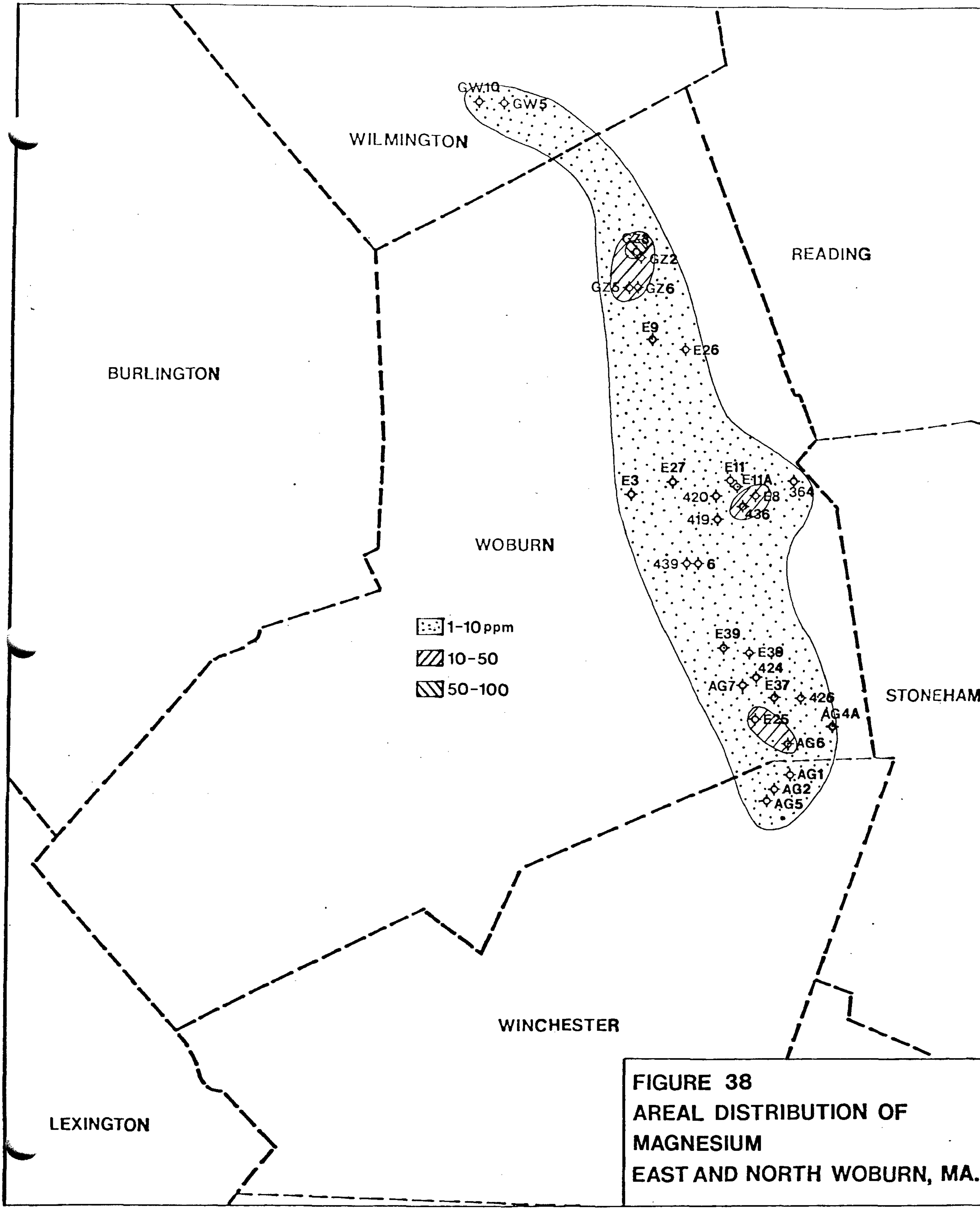


FIGURE 38
AREAL DISTRIBUTION OF MAGNESIUM
EAST AND NORTH WOBURN, MA.

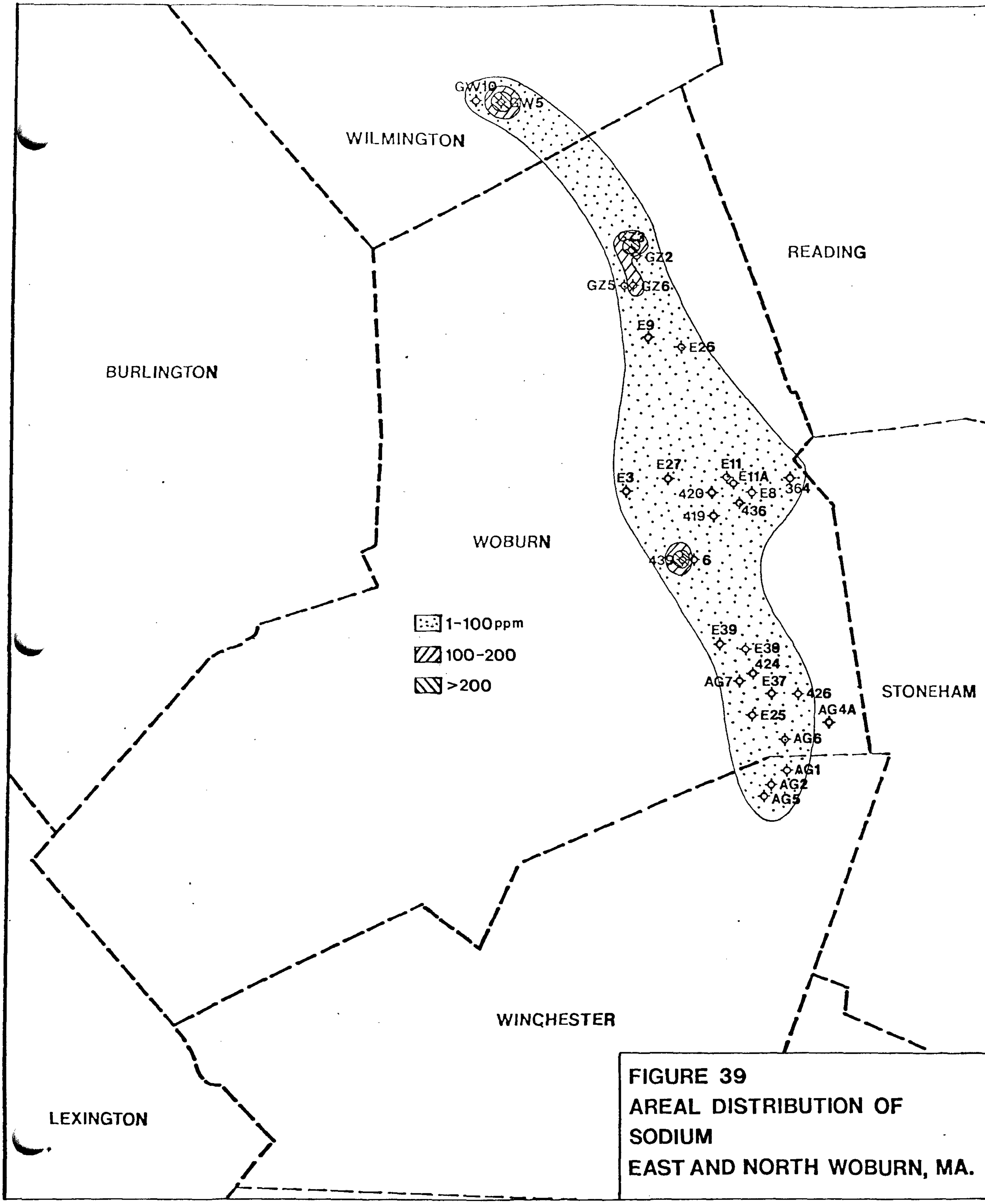


FIGURE 39
AREAL DISTRIBUTION OF SODIUM
EAST AND NORTH WOBURN, MA.

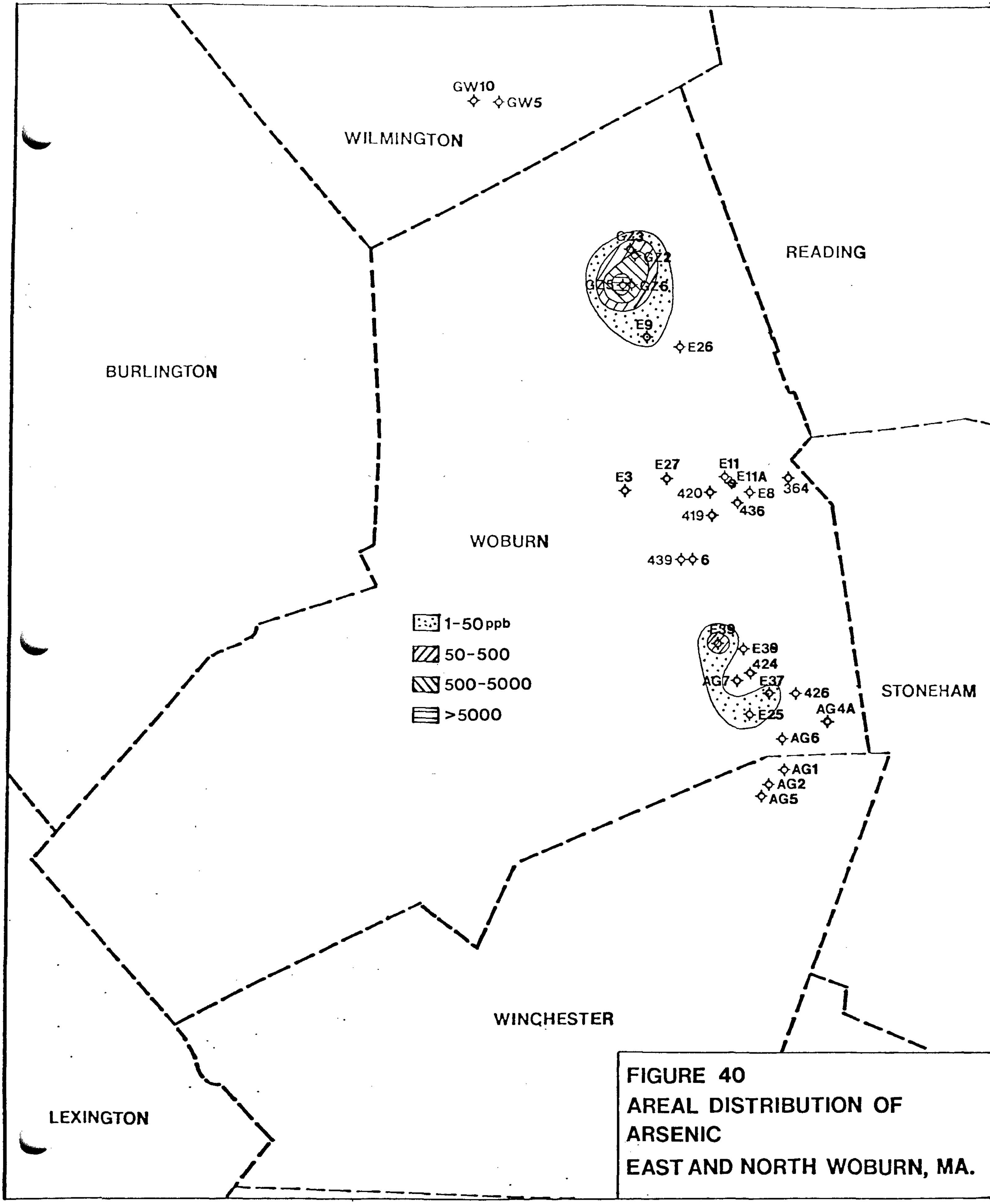


FIGURE 40
AREAL DISTRIBUTION OF ARSENIC
EAST AND NORTH WOBURN, MA.

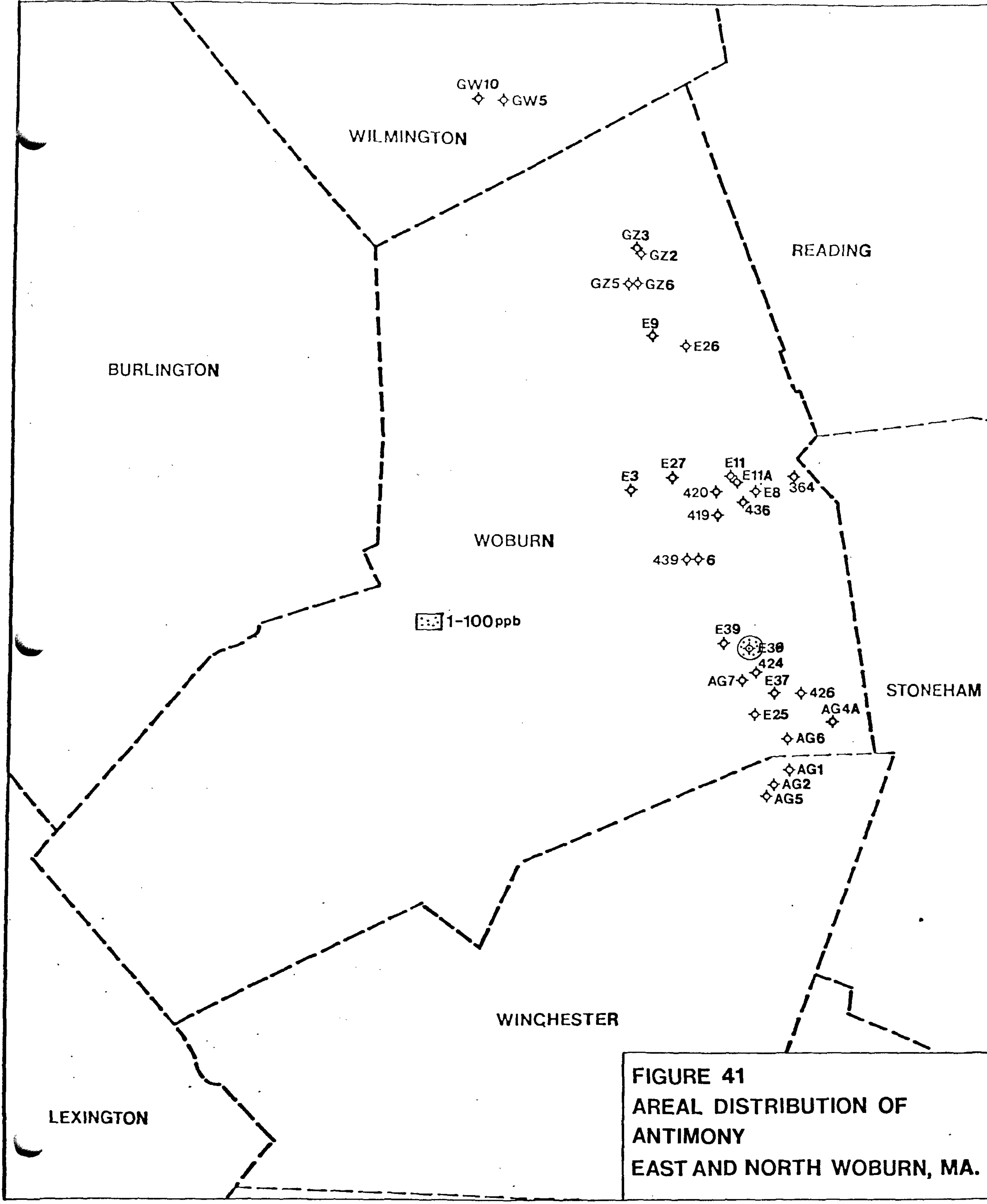


FIGURE 41
AREAL DISTRIBUTION OF ANTIMONY
EAST AND NORTH WOBURN, MA.

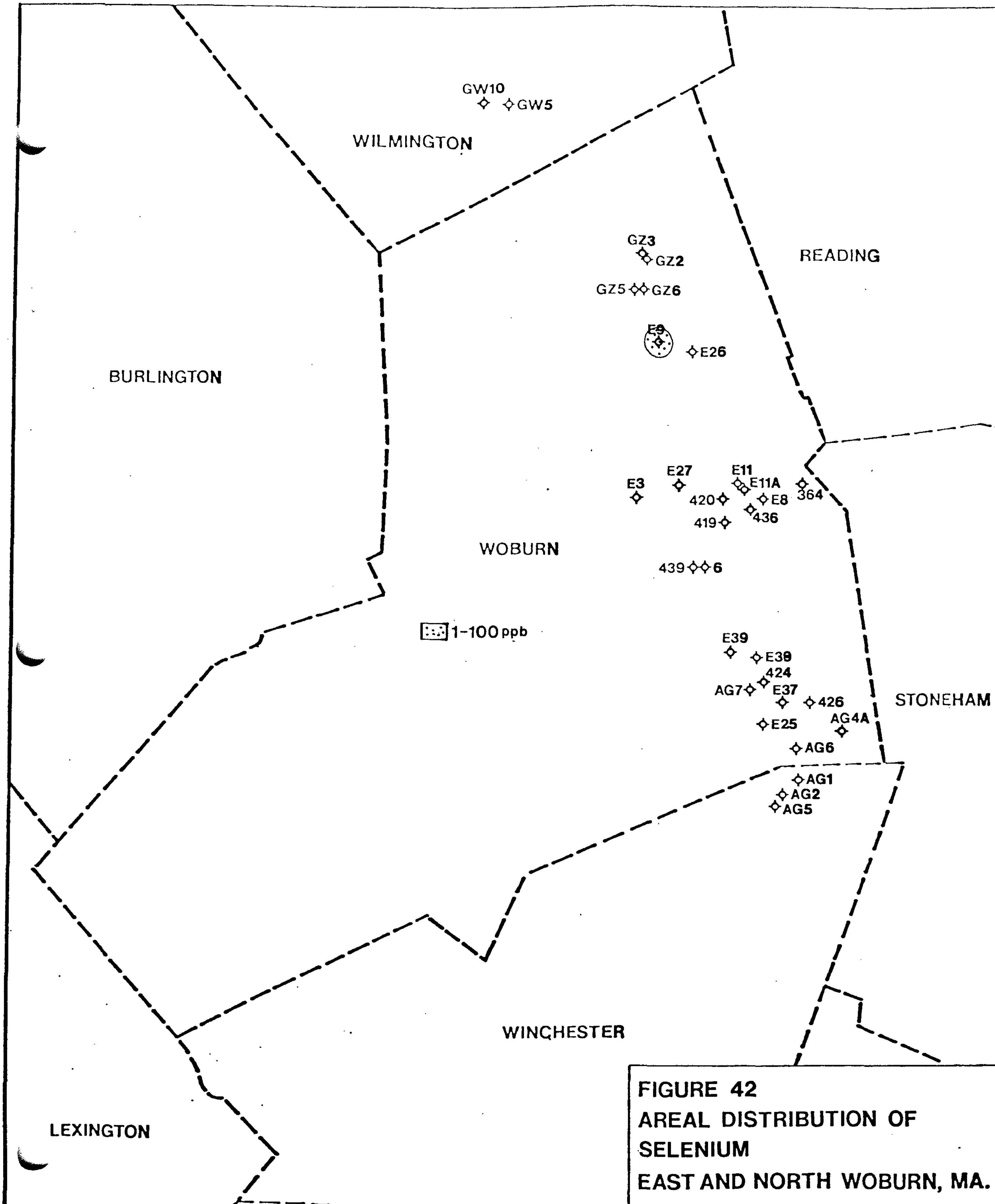


FIGURE 42
AREAL DISTRIBUTION OF SELENIUM
EAST AND NORTH WOBURN, MA.

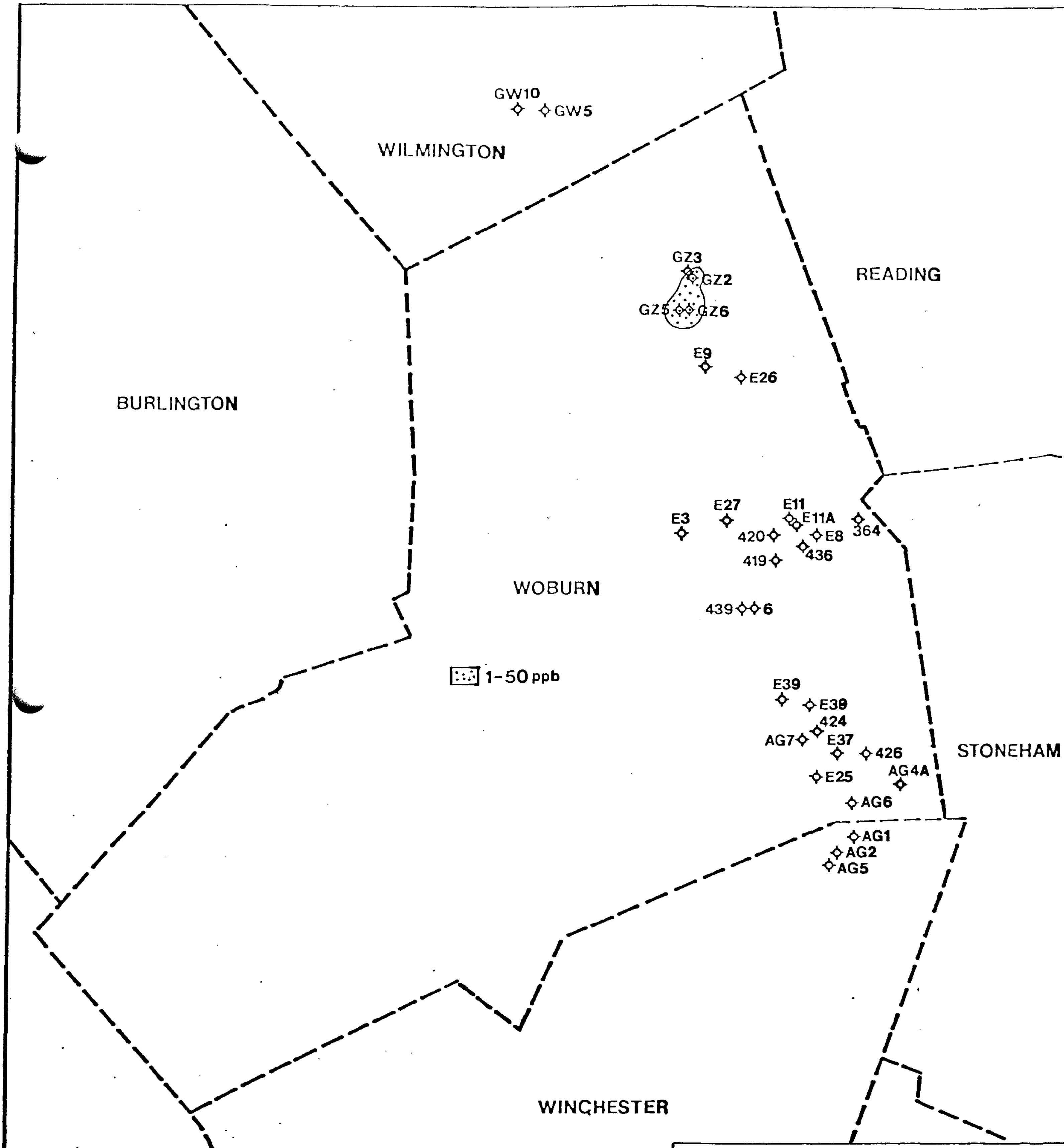


FIGURE 43
AREAL DISTRIBUTION OF THALLIUM
EAST AND NORTH WOBURN, MA.

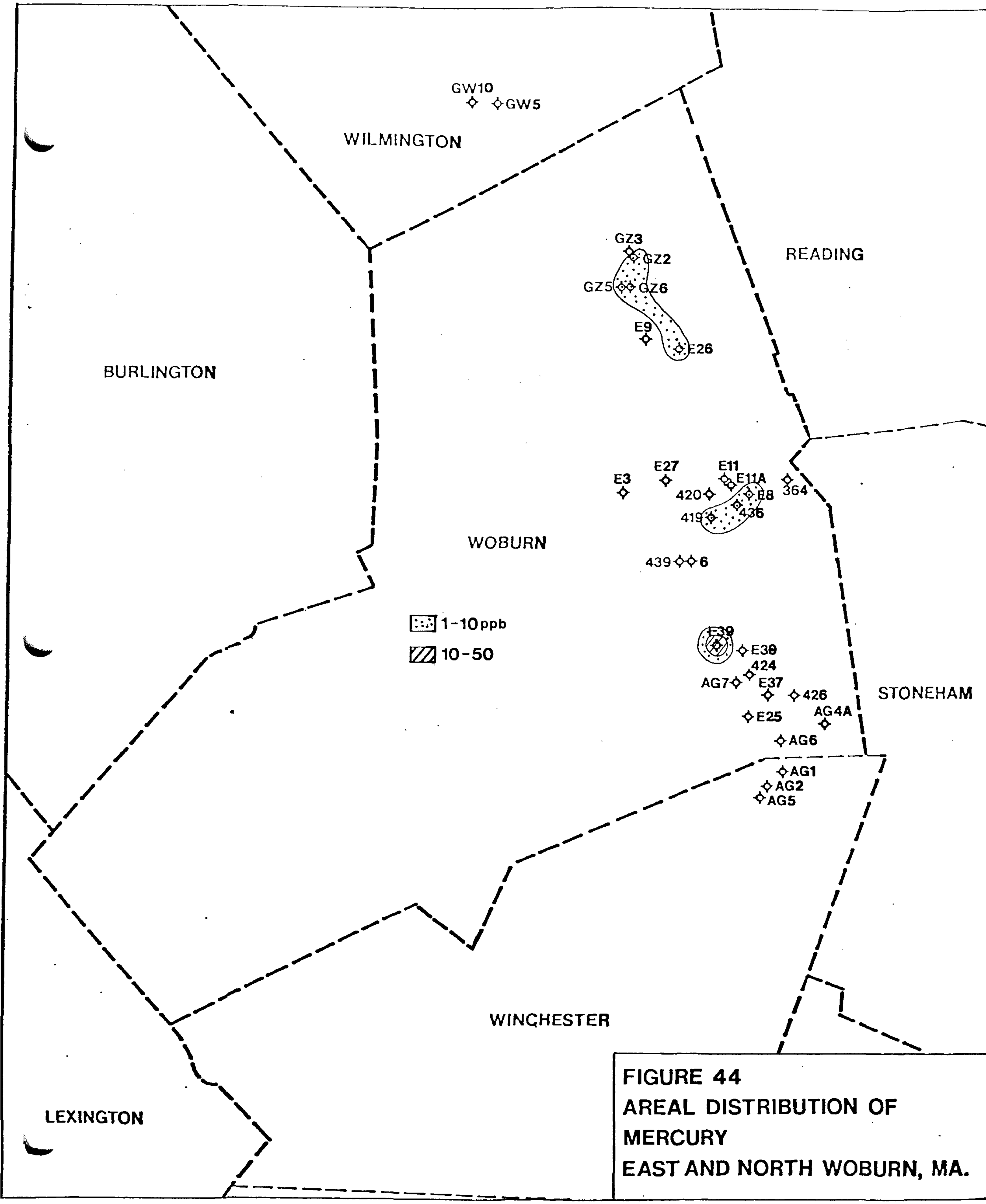


FIGURE 44
AREAL DISTRIBUTION OF MERCURY
EAST AND NORTH WOBURN, MA.

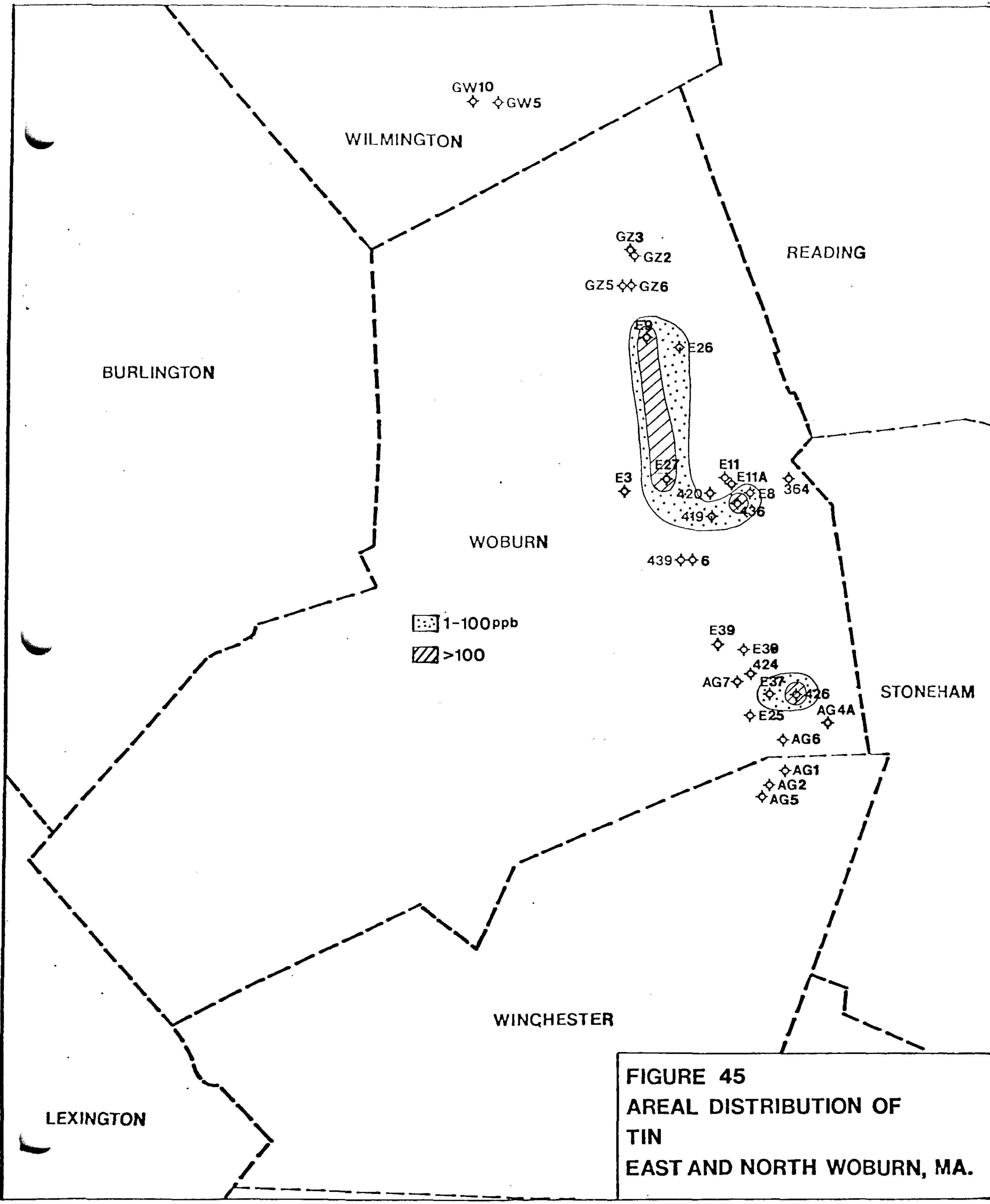


FIGURE 45
AREAL DISTRIBUTION OF TIN
EAST AND NORTH WOBURN, MA.

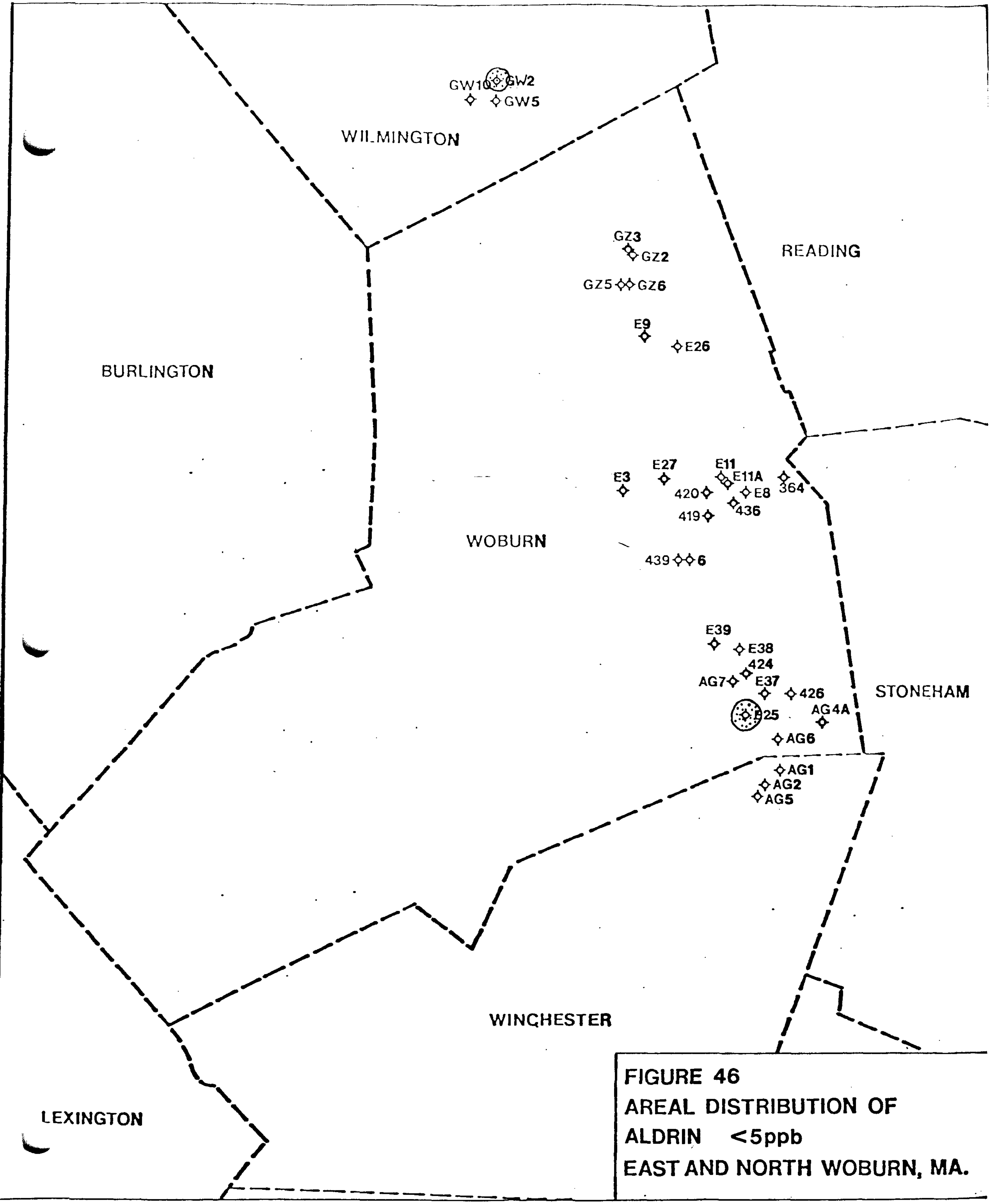


FIGURE 46
AREAL DISTRIBUTION OF
ALDRIN <5ppb
EAST AND NORTH WOBURN, MA.

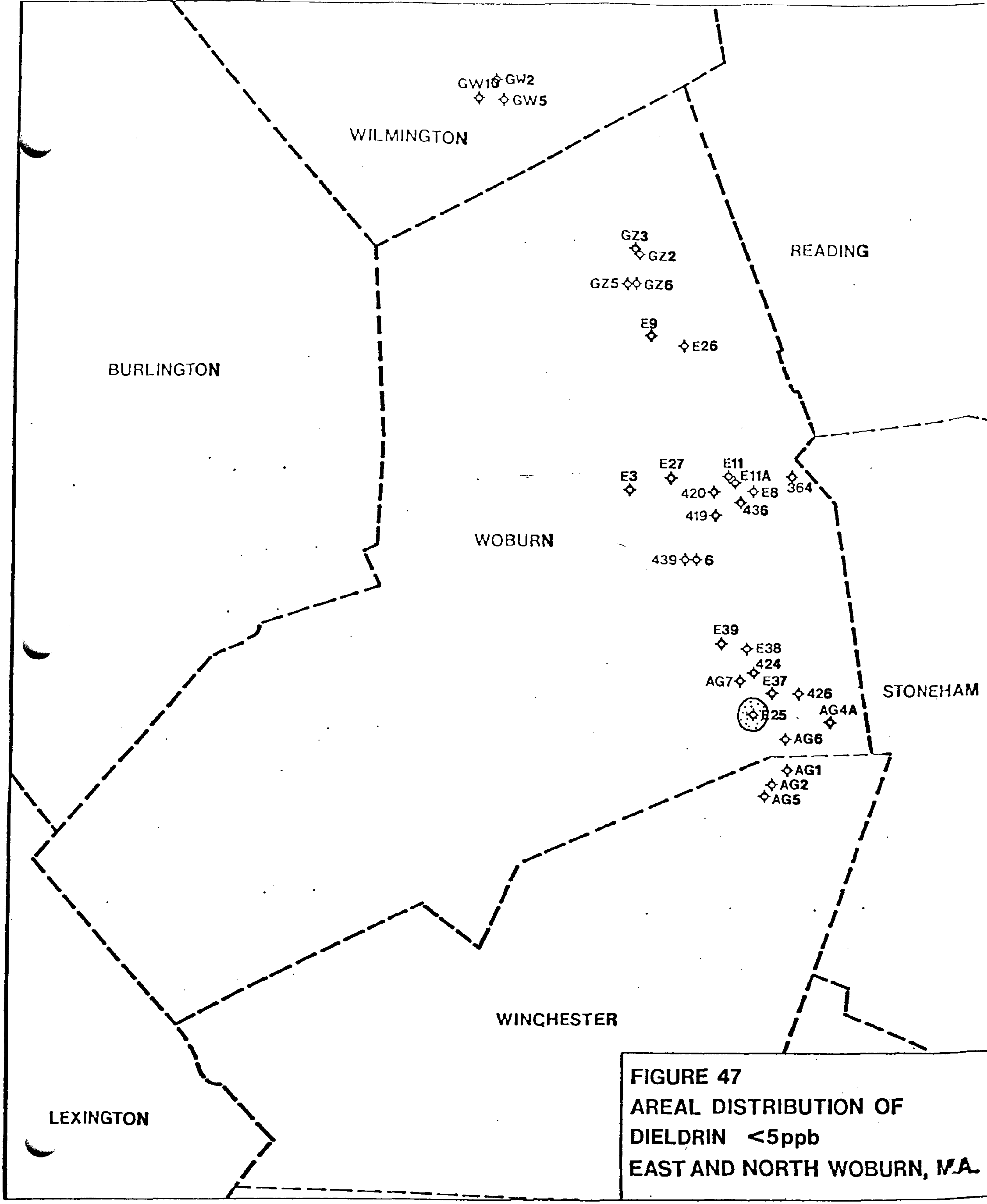


FIGURE 47
AREAL DISTRIBUTION OF
DIELDRIN <5ppb
EAST AND NORTH WOBURN, MA.

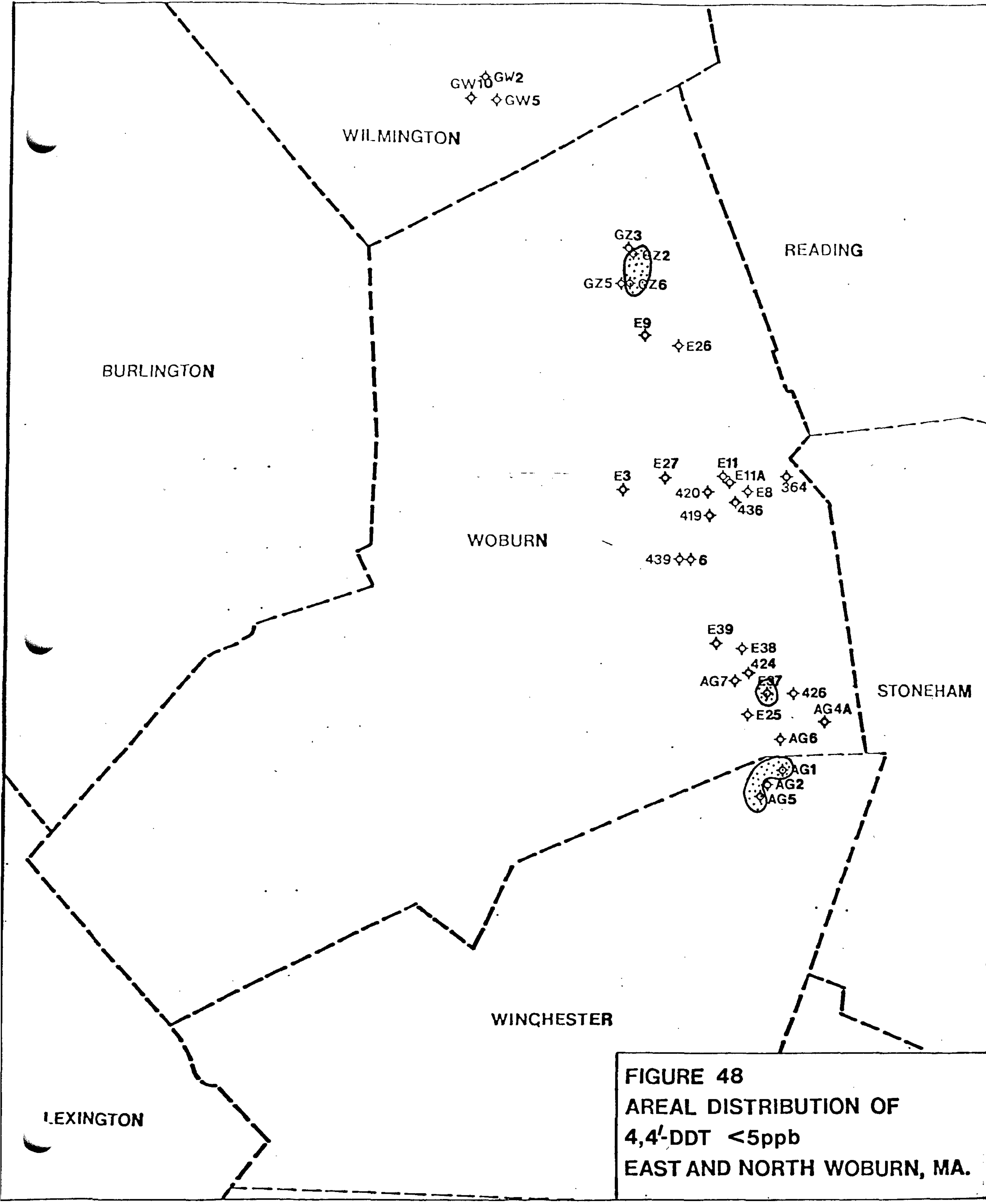


FIGURE 48
AREAL DISTRIBUTION OF
4,4'-DDT <5ppb
EAST AND NORTH WOBURN, MA.

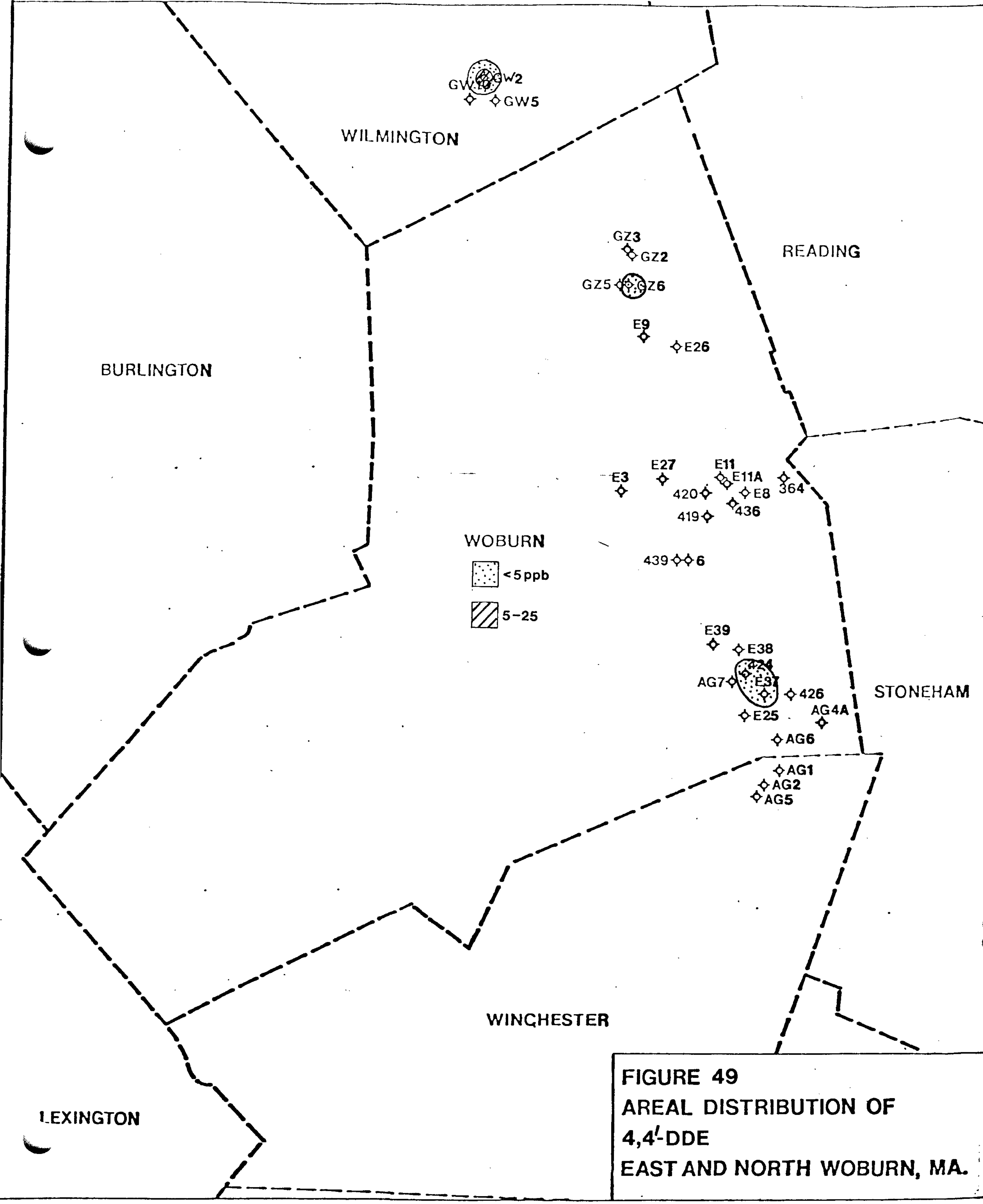


FIGURE 49
AREAL DISTRIBUTION OF
4,4'-DDE
EAST AND NORTH WOBURN, MA.

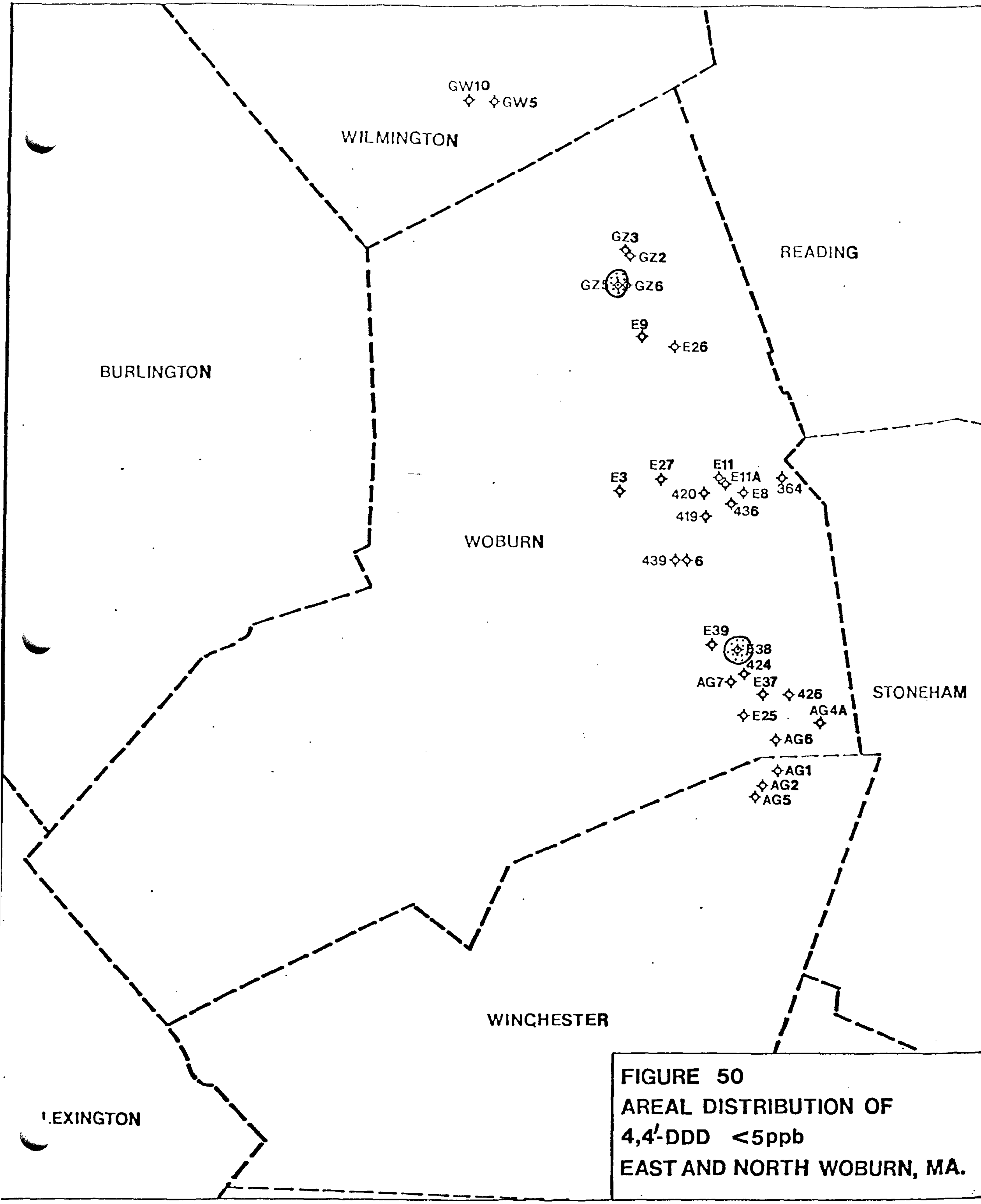


FIGURE 50
AREAL DISTRIBUTION OF
4,4'-DDD <5ppb
EAST AND NORTH WOBURN, MA.

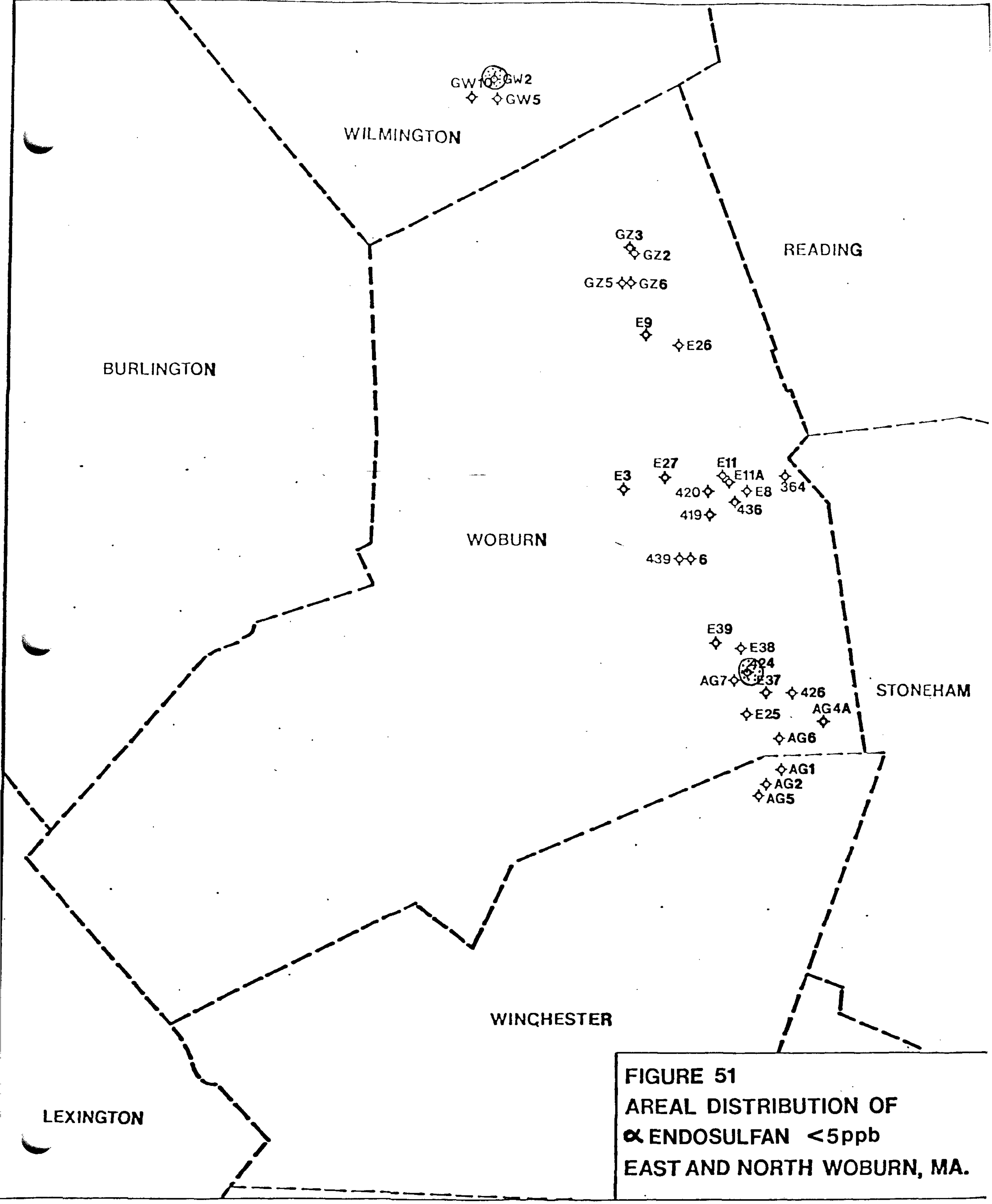


FIGURE 51
AREAL DISTRIBUTION OF
α ENDOSULFAN <5ppb
EAST AND NORTH WOBURN, MA.

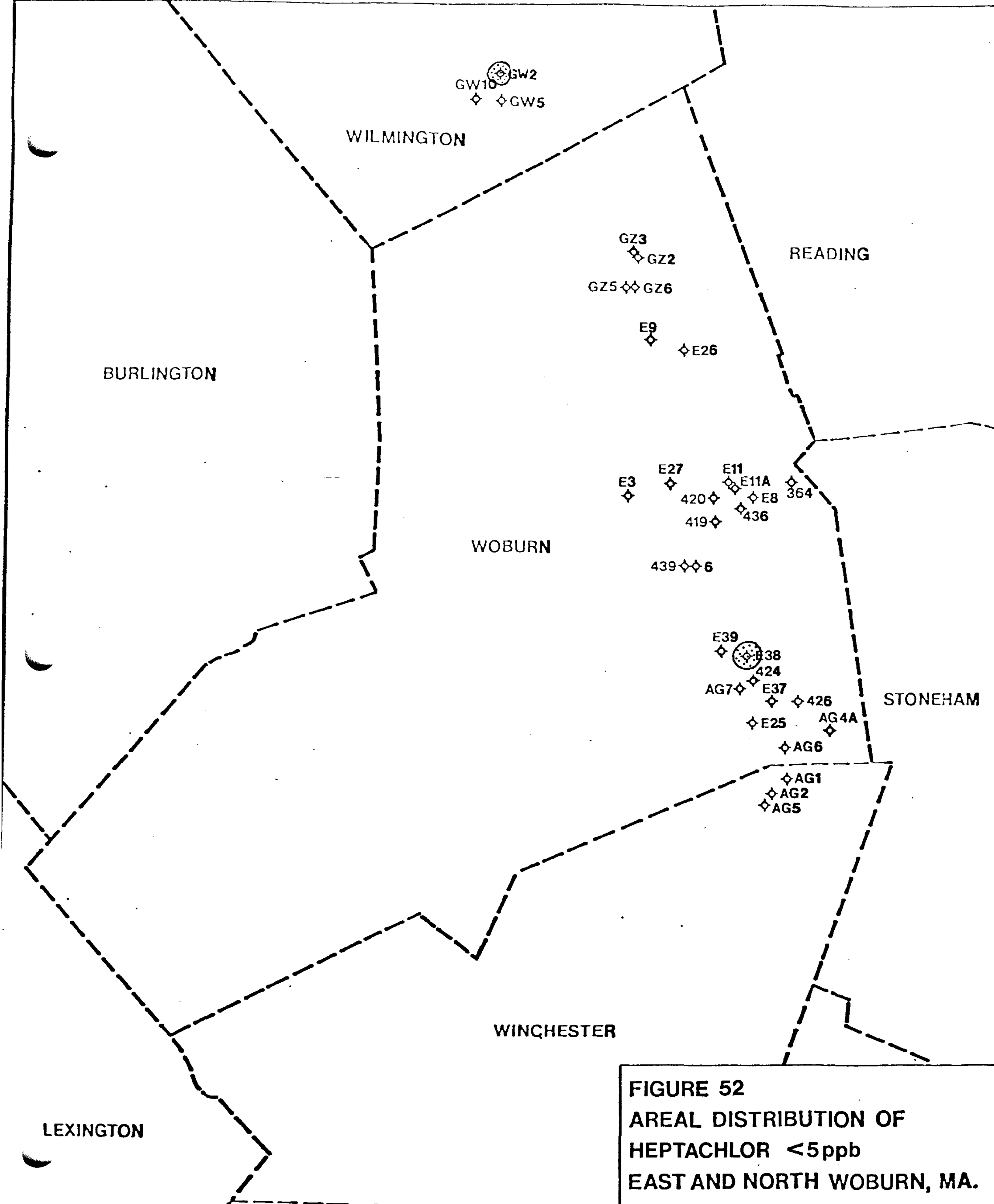


FIGURE 52
AREAL DISTRIBUTION OF HEPTACHLOR <5ppb
EAST AND NORTH WOBURN, MA.

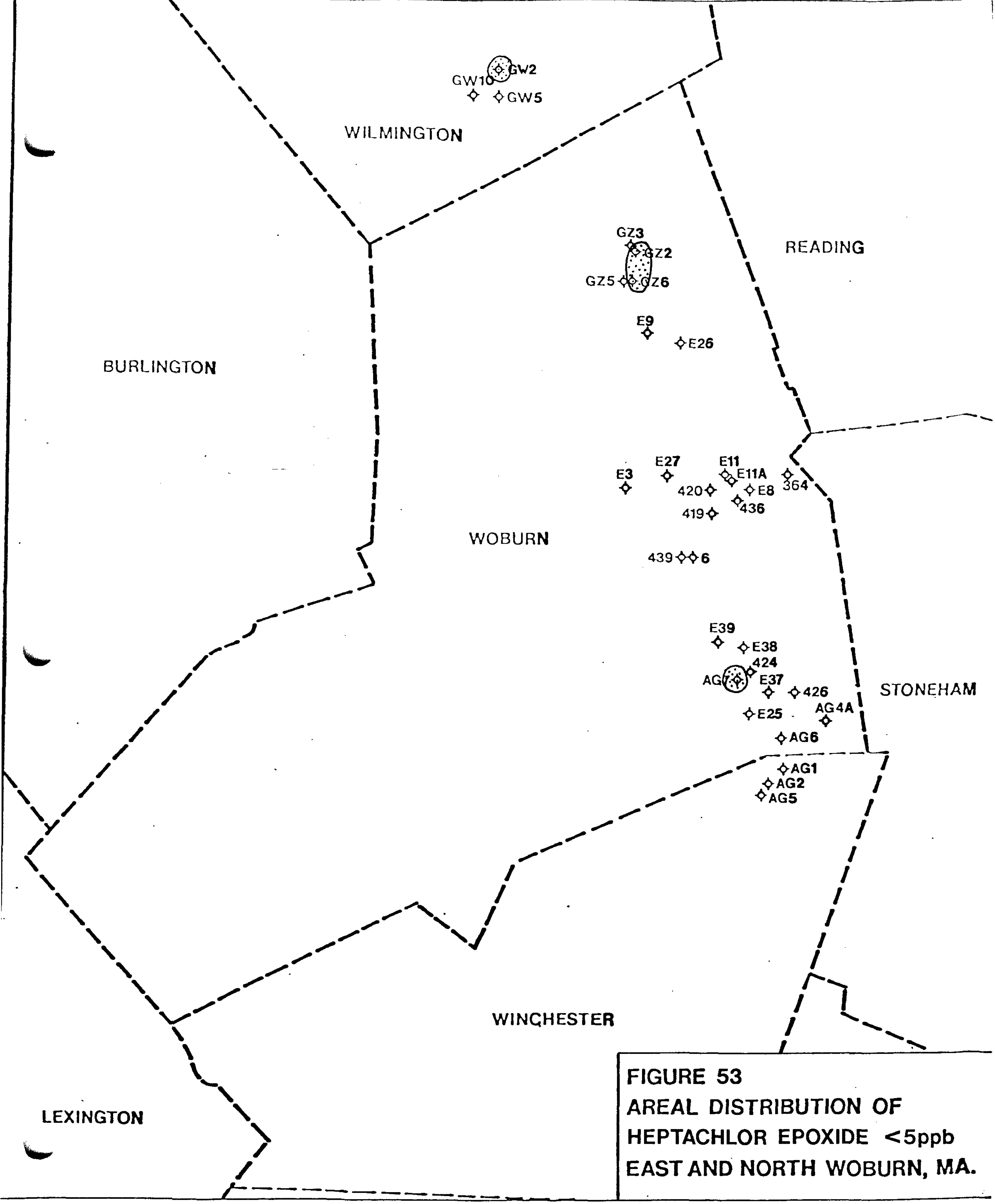


FIGURE 53
AREAL DISTRIBUTION OF HEPTACHLOR EPOXIDE <5ppb
EAST AND NORTH WOBURN, MA.

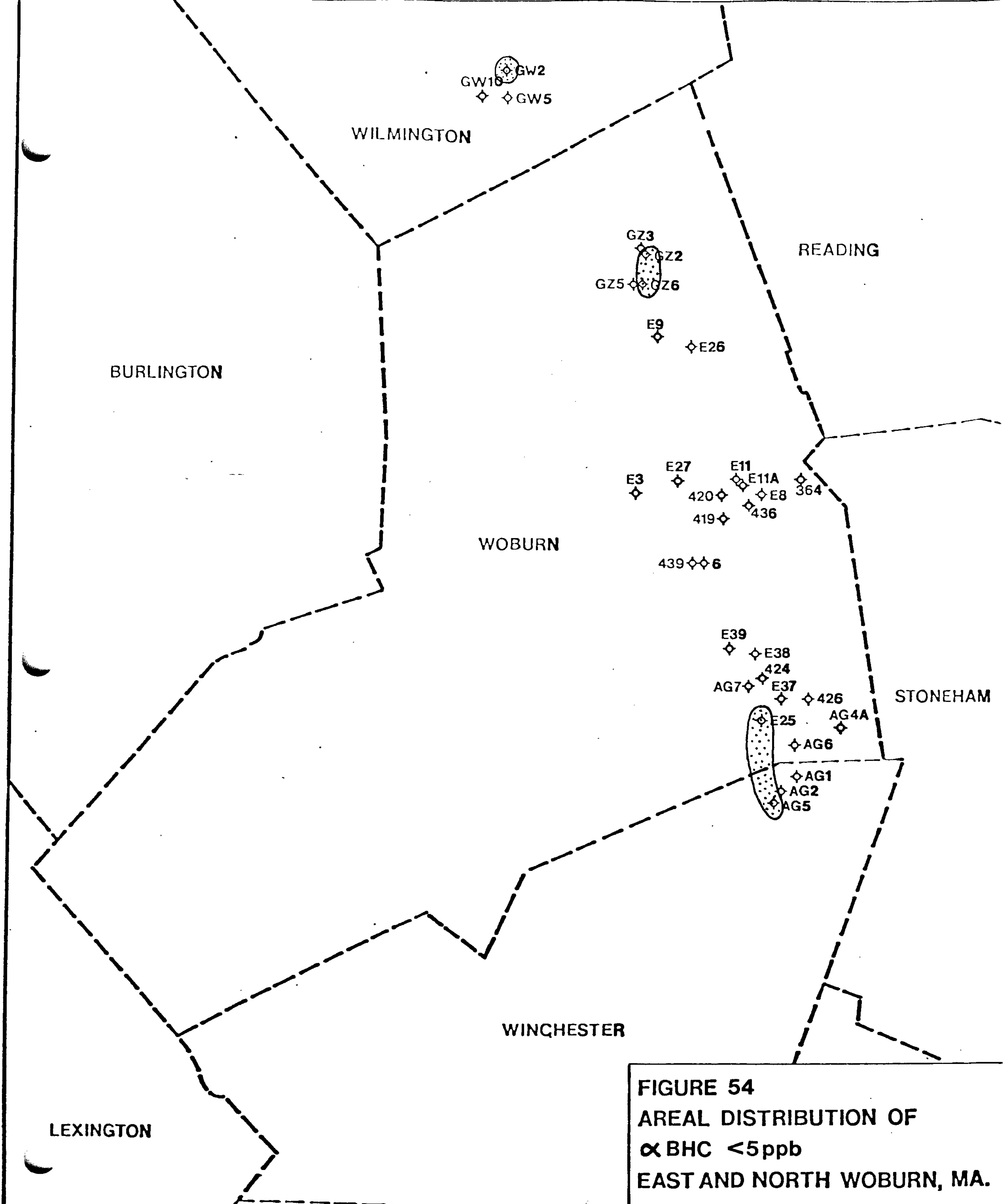


FIGURE 54
AREAL DISTRIBUTION OF
α BHC <5ppb
EAST AND NORTH WOBURN, MA.

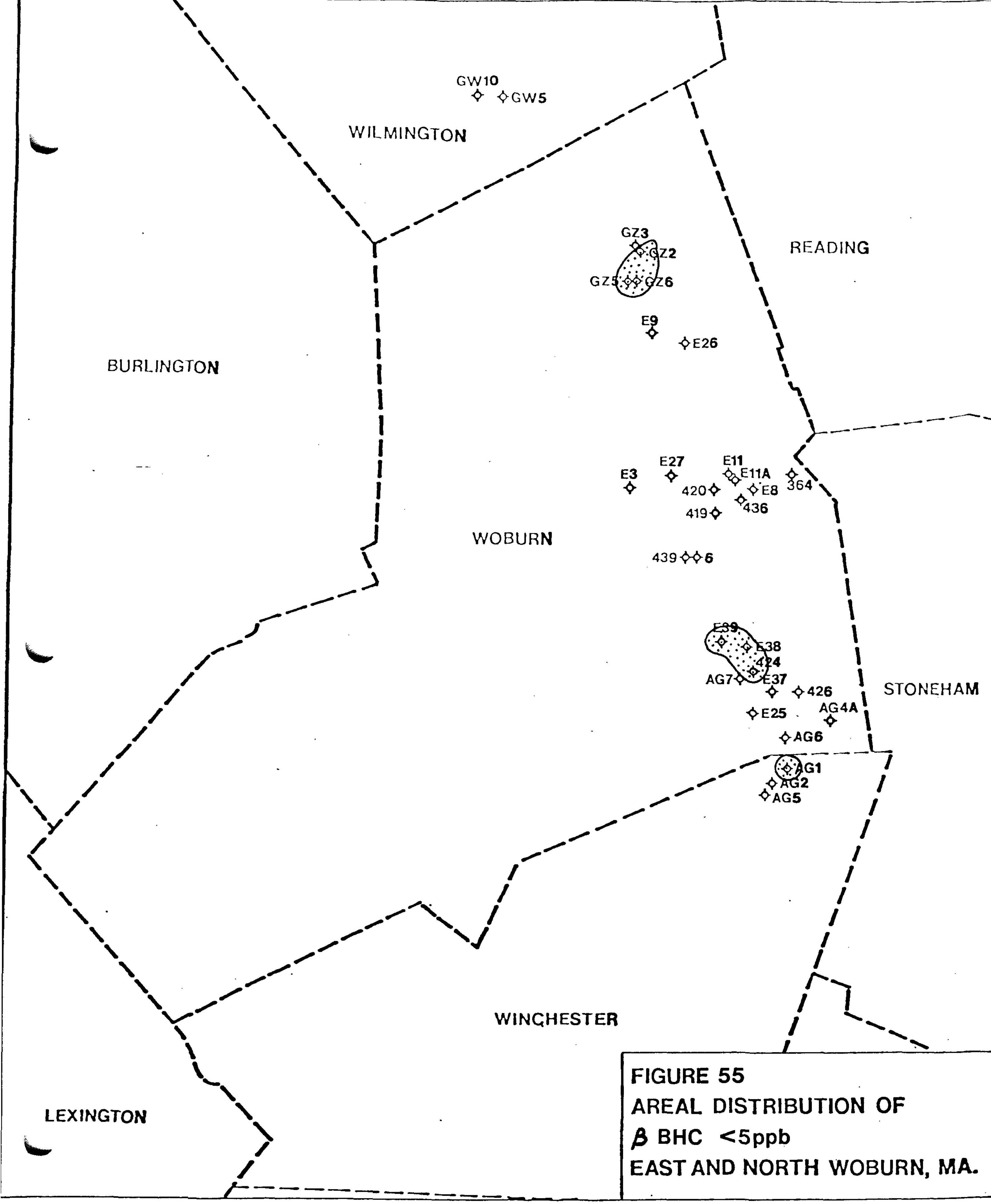


FIGURE 55
AREAL DISTRIBUTION OF
β BHC <5ppb
EAST AND NORTH WOBURN, MA.

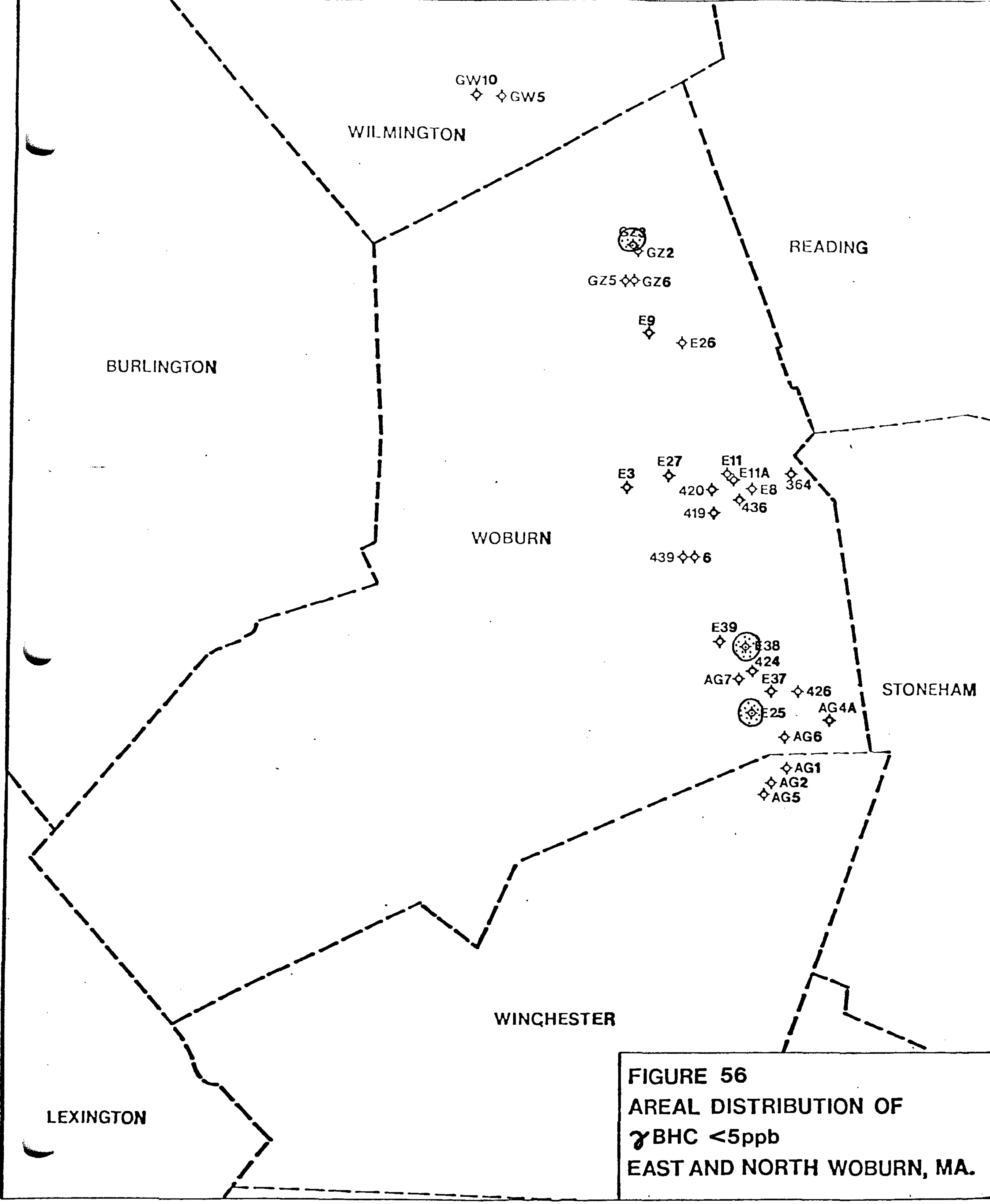


FIGURE 56
AREAL DISTRIBUTION OF
γBHC <5ppb
EAST AND NORTH WOBURN, MA.

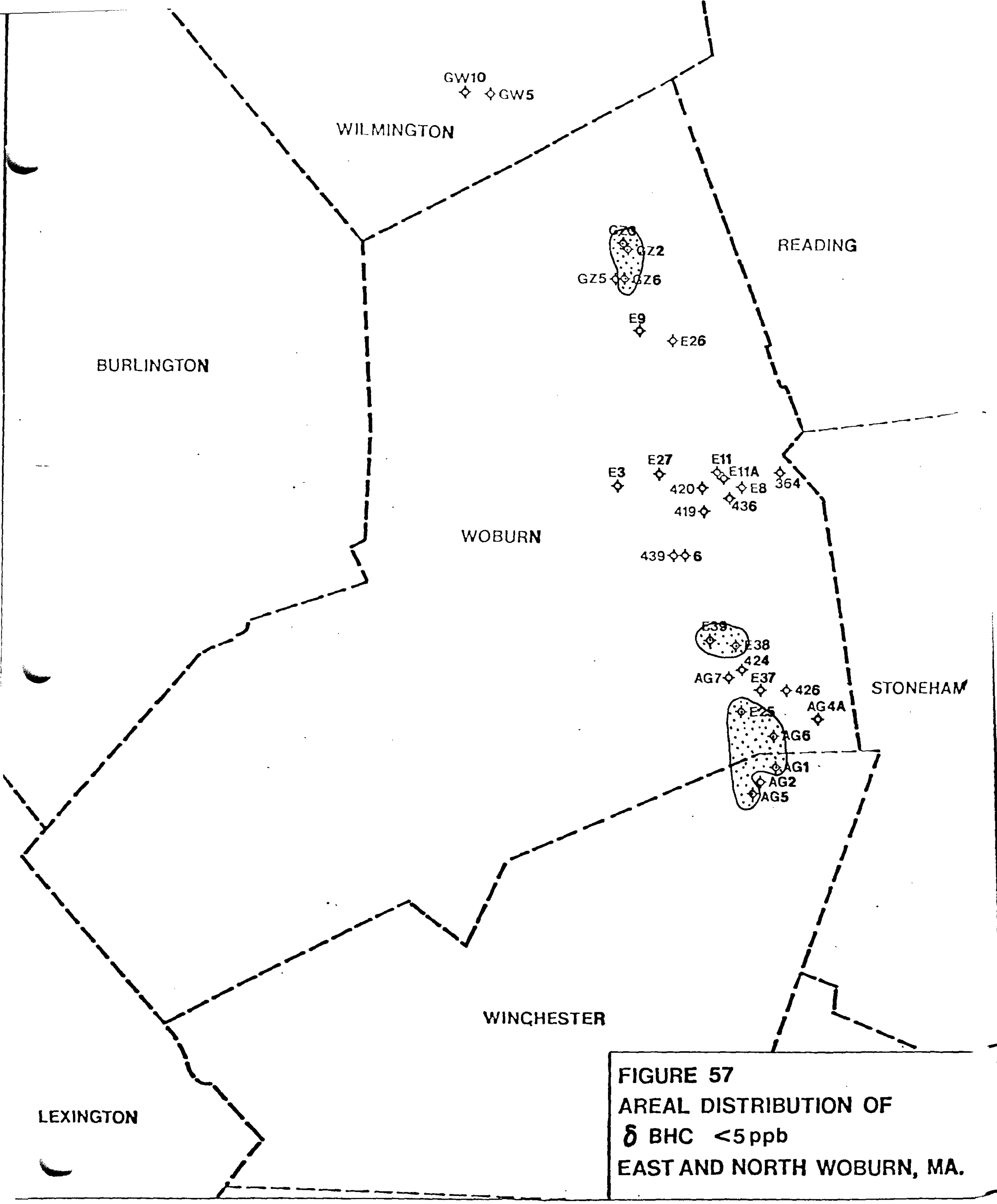


FIGURE 57
AREAL DISTRIBUTION OF
δ BHC <5 ppb
EAST AND NORTH WOBURN, MA.

SECTION 5 - HUMAN HEALTH EFFECTS

5.1 INTRODUCTION

The presence of chemical contaminants in samples of groundwater raises questions regarding potential contamination of drinking water supplies, and therefore concern over possible human and environmental health effects.

Chemicals can enter the environment in general, and groundwater in particular from four major sources: a) industrial processes and industrial waste, b) agricultural operations, c) domestic and urban chemical use, and d) naturally occurring sources. The behavior of a chemical once it has been introduced to groundwater depends on the physicochemical properties of the chemical including water and lipid solubility, ionic strength, and vapor pressure, and the processes and conditions present within the aquifer. The potential effects of a chemical on humans and on the environment result from interaction of all forces acting on the chemical and on the environmental system in which the chemical is contained. Also critically important are the intrinsic toxicological properties of the chemical. This section will describe known and suspected human health effects associated with chemicals detected through laboratory analysis of groundwater samples collected in the study area of Woburn, Massachusetts. This section will also discuss the environmental effects and chemodynamic properties of several of these chemicals. References 10 to 17 were consulted during the writing of this section.

5.2 BACKGROUND INFORMATION

Toxicology is the study of adverse effects of foreign substances on living organisms. In this context, a foreign substance is one which is not a required nutrient or a normal foodstuff for the organism in question.

5.2 Background Information - continued

Toxicology is a relatively new science which developed from the science of pharmacology, which is the study of the effects of drugs and therapeutic substances on humans and other organisms. Much of the human toxicological information available on the harmful effects of chemicals other than drugs has been derived in the last 20-30 years. The apparent widespread occurrence of synthetic chemicals in the environment has been a major impetus in this development of current toxicological knowledge. Despite the many recent toxicological findings, there are several unknowns regarding effects of chemical exposure on people.

There are three major shortcomings in much of the currently available toxicology data: 1) Most of the information available detailing specific effects of specific chemicals have been derived from animal experimentation. In fact, very little toxicological data exist which directly relate human health effects of chemicals. When human data are available, they usually were obtained from study of a massive chemical exposure, often the result of an industrial accident, or a suicide attempt. For the most part, toxicity studies are performed in animals which can be exposed to a chemical, killed and then studied in detail. The information obtained from such studies is then extrapolated to man. 2) Very little information describing effects of low levels of chemicals is available. In the last decade, much experimental work in this area has been done, but most of the descriptive toxicology reported in the literature describe effects of large doses of chemicals. 3) There is almost no research on the effects of mixtures of chemicals on people or animals. This is an area of great concern, because most incidences of environmental contamination involve more than one chemical substance.

Despite these problems, toxicological data obtained from animal studies are still useful in predicting human response. Proper assessment of toxicity data depends, however, on an understanding of the relationship between animal models and man, and knowledge of how chemicals can react in the body to produce responses.

5.2 Background Information - continued

An understanding of the following concepts is essential to proper evaluation of toxicological information. In the following discussions, the information presented will refer to humans, unless otherwise specified.

Chemicals may produce acute or chronic effects on the body.

The term acute refers to responses which occur after a single short-term exposure to a substance. It does not refer to the magnitude or severity of the exposure or the response. Acute effects are generally noticed after exposure to a large dose of a chemical, because single exposures to small quantities of most substances do not produce serious toxic effects.

Chronic refers to long term exposure, or exposure to repeated doses of a substance. As with the term acute, the work chronic, when used by toxicologists, does not refer to the seriousness of the response. Chronic effects of chemical exposure range from the mild dermatitis (skin irritation) that affects some people after repeated exposure to dishwashing detergent, to cancer.

Toxic effects are also classified as local or systemic.

A local effect is one which occurs at the site of body contact with the chemical. Local effects can result from either acute or chronic exposures. Dermatitis is a chronic, local response; respiratory irritation after inhaling ammonia is an acute, local effect.

Systemic (whole body) effects are those which occur throughout the body, or at a particular site in the body removed from the point of contact. Systemic effects can also result from acute or chronic exposure. Cancer is a chronic, systemic response to chemical insult; intoxication from alcohol ingestion is an acute, systemic response.

5.2 Background Information - continued

Chemicals can get into the body by any of four mechanisms: inhalation, ingestion, absorption through the skin, and direct injection into the bloodstream. Ingestion is by far the most relevant to this discussion. Inhalation hazards can result from groundwater contamination if the chemical contaminant is present in concentrations greater than its limit of solubility in water, and if the substance volatilizes at low temperatures. If these conditions are present, a volatile chemical in groundwater will also be present in the vapor state at any locations where the water comes into contact with the atmosphere, such as in wells or in discharge zones. Skin absorption hazards may result from groundwater exposure if high concentrations of chemicals are present.

Ingestion of chemical contaminants in water is an obvious hazard which must be considered in any location where contaminated groundwater has been identified.

After they are taken into the human body, chemicals are acted upon by body systems in various ways. The overall response of the body to chemicals is called pharmacokinetics. The four pharmacokinetic processes by which the body acts on foreign chemicals are absorption, distribution, metabolism and excretion. Absorption is transport from outside the body to inside, by passage of the substance through body membranes. Distribution is the process of mobilization of a chemical to the body site where it will be stored or metabolized. Storage is a form of distribution. Lipid-soluble chemicals tend to be stored in body fat, where they may remain for long periods of time. Metabolism is the sum of the processes by which the body changes a chemical from one form to another. Metabolism occurs to some extent in all body organs, but the liver is the principal site of metabolism. Foreign chemicals are metabolized by the same enzymes and enzyme systems that the body uses to metabolize essential nutrients. Metabolism of chemicals may result in their detoxification; often, however, the body transforms a chemical into metabolites (products of metabolism) which are more toxic than the parent compound. One major reason for

5.2 Background Information - continued

metabolism is to produce a substance which is more water soluble than the original chemical. In most cases chemicals cannot be removed from the body unless they are water soluble. Excretion is the process of removal of a chemical from an organism. The kidneys are the principal organs of excretion. Excretion of chemicals also occurs through exhalation, through sweat, in bile and feces, and in milk. Lipid soluble material may be excreted in bile and in milk.

Toxic effects of chemicals generally occur at the body sites where pharmacokinetic processes take place: therefore at the site of entry (absorption), in all areas to which the chemical was transported (distribution) and at the organs of metabolism and excretion. The liver and kidneys are the body organs most often at risk to toxic chemicals.

5.3 CONCENTRATION AND DOSE

The terms concentration and dose must be differentiated in order to assess toxicity of a chemical. The concentration of a chemical is the amount of the chemical present in the supporting medium. In water, the terms parts per million (ppm) and parts per billion (ppb) are used. The metric equivalents of these concentrations are milligrams per liter and micrograms per liter, respectively. A concentration of one microgram per liter (1 ppb) is one microgram of a substance contained in a liter of water.

Dose is the amount of a substance absorbed by an organism. Dose is generally calculated in terms of milligrams or micrograms of the chemical per kilogram body weight of the organism.

The concentration and dose values do not correspond with each other. In order to determine the dose received by an organism, it is necessary to know the weight of the organism, the concentration of the chemical in the medium in which it is contained, and the total amount of the medium to which the organism was exposed. For example, if a 70 kg (150 lb) man drinks 2 liters of water which contained 10 ppb toluene, his total dose can be calculated as follows:

$$10 \text{ ppb} \times \frac{1 \text{ ug/liter}}{\text{ppb}} \times 2 \text{ liter} \times \frac{1}{70 \text{ kg}} = .29 \text{ ug/kg}$$

5.3 Concentration and Dose - continued

The total dose received by the person in this case is approximately .3 ug/kg. If the person drinks 2 liters of water per day, which is the standard estimate of U.S. water consumption, his dose would be .3 ug/kg/day, which calculates to 110 ug/kg/year.

The total amount of toluene ingested by this person in one year as a result of drinking water would be 7700 ug (7.7 mg or 0.008 grams).

The goal of toxicological assessment of chemical contamination in the environment must be to determine whether ingestion or other exposure to such seemingly small quantities of foreign chemicals has adverse effects on people.

5.4 POTENTIAL HUMAN HEALTH EFFECTS OF CHEMICALS IDENTIFIED IN STUDY AREA GROUNDWATER, WOBURN, MASSACHUSETTS

5.4.1 Chlorinated Organic Chemicals

The chlorinated volatile organics are widely used as solvents. They all have excellent solvent ability and are generally not flammable, two properties which contribute to their wide acceptance in industry. One property which the chlorinated volatile organics have in common is their ability to produce anesthesia and central nervous system depression after inhalation of large quantities. Very little human data exist concerning effects of chronic ingestion of small quantities of chlorinated solvents.

The chlorinated organics listed here all behave similarly in the environment. They all volatilize at ambient temperatures, creating the potential of vapor hazards in areas where groundwater discharge occurs. The chlorinated organic solvents have densities greater than 1.000 and are all only slightly soluble in water. They are lipophilic, or oil-soluble, materials, and have a high affinity for oils, other organic solvents and sediments with low ionic strength.

5.4.1 Chlorinated Organic Chemicals - continued

The following chlorinated volatile organics were detected in the groundwater of the Woburn study area:

1,1,1-Trichloroethane - also called methyl chloroform, is one of the most widely used industrial solvents and metal degreasers. 1,1,1-Trichloroethane has been regarded as one of the "safest" industrial solvents. Most of the human toxicity data on 1,1,1-trichloroethane come from studies of industrial inhalation exposures. Levels of 1,1,1-trichloroethane ranging from 1000 ppm to 2000 ppm in air have been reported to cause uncoordination and "drunken" behavior. At slightly lower air exposure levels, human subjects report drowsiness. The toxicological significance of long-term ingestion of 1,1,1-trichloroethane is unknown. Data obtained from animal studies indicate that the liver is affected at near-lethal doses, in the range of 700-1000 mg/kg.

1,2-trans-Dichloroethylene - also known as acetylene dichloride, is used as a general purpose solvent and in the manufacture of perfumes, lacquers, thermoplastics and pharmaceuticals. There is no evidence that low concentrations of 1,2-trans-dichloroethylene constitute a human health hazard.

1,1-Dichloroethylene - or vinylidine chloride, is used in the synthesis of saran and other copolymers. It is also used in the manufacture of some adhesives. Unlike its isomer 1,2-trans-dichloroethylene, vinylidine chloride is known to be toxic by ingestion in animals. Liver damage is the most common effect. Although there are no human data, 1,1-dichloroethylene should be treated as a potential human liver toxin (hepatotoxin). There is also evidence that lifetime ingestion of 1,1-dichloroethylene causes tumors in laboratory animals, but there are no data linking it to cancer in people.

1,1-Dichloroethane - also known as ethylidene chloride, is used as an extraction solvent and in the synthesis of pharmaceuticals. The toxicological properties of 1,1-dichloroethane have not been studied extensively. It has been shown to cause liver injury when fed to laboratory animals over their lifetime in high doses.

5.4.1 Chlorinated Organic Chemicals - continued

1,2-Dichloroethane, - or ethylene dichloride, is used in chemical syntheses, as a solvent and degreaser, and in paint, finish and varnish remover. It has been used as an additive in leaded gasoline. 1,2-Dichloroethane vapor is highly toxic. Damage to both the respiratory tract and the cornea of the eye may result from prolonged exposure to 1,2-dichloroethane vapor. There is evidence that long term ingestion of 1,2-dichloroethane may result in liver and kidney damage. This substance has been demonstrated to cause tumors in rats and mice exposed over their lifetimes. There are no data linking 1,2-dichloroethane with human cancer, but, on the strength of the animal data, it should be considered a potential human carcinogen.

Methylene chloride - or dichloromethane, is used as a paint remover, solvent, degreaser, and propellant for aerosols. Methylene chloride is highly volatile, even at low temperatures. The vapor is extremely hazardous to the eyes. When inhaled, methylene chloride is metabolized to carbon monoxide by humans, and carboxyhemoglobinemia, a condition in which the blood hemoglobin will not carry sufficient oxygen, results. It is unknown if this effect will also result from ingestion of methylene chloride. Very little is known regarding chronic toxicity of ingested methylene chloride in people.

Chloroform - or trichloromethane, is used in the manufacture of fluorocarbon propellants and refrigerants, fluorocarbon plastics, and some insecticides. It is also used as a solvent. Chloroform is no longer used as an anesthetic, and the Food and Drug Administration (FDA) has banned its use in throat lozenges and other pharmaceuticals. Chloroform is a neurological and liver toxin in man, and lifetime exposure has been shown to cause cancer in several species of laboratory animals. Although there is no direct evidence linking chloroform with human cancer, it is considered a potential human carcinogen.

Chloroform is a common contaminant in natural waters in the United States. There is some evidence that the use of chlorination as a disinfectant in wastewater treatment plants may result in the formation of chloroform and other chlorinated organics. Recently, the United States EPA established a drinking water Maximum Contaminant Level of 100 ppb for chloroform. This level constitutes an enforceable standard in public drinking water for suppliers serving over 75,000 persons.

5.4.1 Chlorinated Organic Chemicals - continued

Carbon tetrachloride - is used in the manufacture of chlorofluorocarbon refrigerants and propellants, in agriculture as a soil fumigant, as a metal degreaser and as a source of chlorine in many commercial organic synthetic processes. Carbon tetrachloride causes liver, kidney and lung injury in humans. Chronic exposure to carbon tetrachloride may cause cirrhosis of the liver. Chronic exposure to carbon tetrachloride causes tumors in laboratory animals and it should be treated as a potential human carcinogen. Because of its extreme liver toxicity, household use of carbon tetrachloride has been banned by the FDA. It is no longer used as a dry cleaning solvent or as a fire extinguishing agent.

Trichloroethylene - commonly called TCE, is used as a metal degreaser, an extraction solvent, a dry cleaning agent, and in chemical synthesis. Trichloroethylene vapor is a recognized hazard in industry, and neurological symptoms have been reported. It is suspected of causing liver injury after chronic vapor exposure. Very little is known regarding effects of chronic ingestion of low levels of trichloroethylene. In lifetime feeding studies, trichloroethylene caused tumors in mice, but not in rats. There is no evidence linking trichloroethylene with human cancer.

Tetrachloroethylene - also called perchloroethylene or PCE, is the most commonly used commercial dry cleaning solvent. It is also used as a vapor degreasing solvent, a drying agent, a heat transfer medium, and an intermediate in the synthesis of fluorocarbons. Tetrachloroethylene has generally been used safely in the dry cleaning and other industries. It is recognized as a vapor hazard which causes neurological symptoms resembling intoxication. There are no data which describe chronic effects of low level ingestion. Tetrachloroethylene has produced tumors in laboratory animals, but there is no evidence which suggests that it causes cancer in man.

5.4.2 CHLOROFLUOROCARBONS

The chlorofluorocarbons are short-chain aliphatic hydrocarbons in which one or more chlorine and fluorine atoms replace the hydrogens. The chlorofluorocarbons are chemically inert, non-flammable, and heat stable to approximately 600°F. They are highly volatile. Many exist in the vapor state at ambient temperatures. They are denser than water and have low surface tensions. They have low water solubilities, but are slightly soluble in organic solvents, oils and lipophilic material. The major industrial uses of chlorofluorocarbons are in aerosol propellants and in refrigerants. Chlorofluorocarbons are used as fire extinguishing agents, lubricants, hydraulic fluids, and dielectric fluids. They are also used in the manufacture of plastics and in air conditioners.

Trichlorotrifluoroethane - or 1,1,2-trichloro - 1,2,2-trifluoroethane has been patented as Freon 113 (DuPont). It is not considered highly toxic. Trichlorofluoroethane is a common refrigerant, air conditioner fluid, and dry cleaning solvent.

Dibromochloromethane - is used in organic synthesis. Its human toxicity has not been studied extensively. Dibromochloromethane vapor is an irritant with narcotic (sleep-inducing) properties.

Trichlorofluoromethane - Freon 11 (Dupont), is used in refrigerators, air-conditioners and fire extinguishers. It also has industrial uses as a solvent and chemical intermediate. Trichlorofluoromethane vapor is a mild irritant. Very few other toxic effects have been reported. There are no data describing its long term human toxicity.

5.4.3 VOLATILE AROMATICS

Four volatile aromatic compounds have been identified in groundwater samples from the study area. Their properties are dissimilar, so they will be discussed separately.

5.4.3 Volatile Aromatics- continued

Benzene - is a non-polar liquid, slightly soluble in water and miscible with other organic solvents. It is less dense than water.

Benzene is used as an intermediate in the synthesis of several commercially-important organic chemicals, as an industrial solvent, and as a gasoline additive. Most incidences of benzene toxicity in humans result from inhalation exposure. These exposures have occurred in industrial settings for the most part. Benzene has been known to cause leukemia in shoe workers exposed to high vapor concentrations. This observation was made by several investigators who studied shoe workers in Italy and Turkey who used a leather glue which contained benzene. Subsequent animal experimentation has indicated that inhalation of high benzene concentrations causes leukemia and tumors in laboratory animals. Leukemias or other tumors have not been detected in animals which were fed benzene, however. There is no evidence that long term ingestion of benzene causes cancer in people.*

Benzene has also been shown to cause blood disorders other than leukemia in people occupationally exposed. These effects have not been demonstrated through ingestion of benzene. Exposure to benzene vapor by benzene workers has also been associated with fatigue, headache, loss of appetite, loss of weight, and menstrual irregularities. Although there are insufficient data describing potential effects of chronic human ingestion of benzene, it should be considered a potential health hazard.

*The cytologic classification of the leukemias detected in the shoe workers exposed to benzene vapor in Italy and Turkey was myelogenous (myelocytic) leukemia, a proliferation of white blood cells of the neutrophilic series. Myelogenous leukemia is not common in children. The leukemias seen in Woburn, Massachusetts between 1969-1979 were for the most part lymphocytic or lymphoblastic leukemias (childhood leukemia). The connection between these distinct cytologic types of leukemia cannot be determined.

5.4.3 Volatile Aromatics- continued

Chlorobenzene - or monochlorobenzene, is used as an industrial solvent, as a reactant in several organic syntheses, and as an intermediate in the synthesis of some chlorinated pesticides. Chlorobenzene is very slightly soluble in water, and miscible with most organic solvents. It is volatile at ambient temperatures and is denser than water. Exposure to high levels of chlorobenzene vapor results in narcosis, and prolonged high level exposure is suspected to cause liver and kidney injury. Chlorobenzene will impart an unpleasant taste to water at concentrations exceeding 20 ppb. There is no evidence that this concentration of chlorobenzene will cause illness or injury, however. No data exist which describe human health effects of long term ingestion of chlorobenzene.

Ethylbenzene - Most of the ethylbenzene produced in the United States is used in the synthesis of styrene. It is also used as an industrial solvent. Ethylbenzene is only slightly soluble in water, and has a specific gravity of 0.867. Ethylbenzene is soluble in most organic solvents. Ethylbenzene vapor has strong irritant properties. There are no data available regarding long term health effects of ingesting small amounts of ethylbenzene.

Toluene - is less dense than water, practically insoluble in water, and soluble in organic solvents and oils. Toluene is an important industrial chemical and is an intermediate in the synthesis of benzene, phenol, benzoic acid, saccharin, pharmaceuticals and cosmetics. it is used as an industrial solvent and in aviation gasoline and high-octane gasoline. Toluene is commonly the solvent present in "model airplane glue", and most of the data on the chronic effects of toluene exposure has come from the study of "glue-sniffers". Liver injury resulting in jaundice along with kidney injury have been reported in people who inhaled large amounts of toluene vapor. There is no information available on chronic effects of drinking water contaminated with toluene.

5.4.4 Extractable Organic Chemicals

Phenol - also called carbolic acid and hydroxybenzene, is a crystalline solid at ambient temperatures and is soluble in water, organic solvents, oils and alkalis. Phenol is

5.4.4 Extractable Organic Chemicals - continued

denser than water. Phenol can volatilize at ambient temperatures, and also forms aerosols. It is used in the synthesis of phenolic resins and other chemicals. Another use is as a solvent for some lubricating oils. Phenol is a strong disinfectant and is used in the manufacture of slimicides, germicides and pharmaceuticals. Five percent phenol solution is a common hospital disinfectant. (It was the first substance used as a surgical disinfectant). Concentrated phenol is highly toxic and can be absorbed through the skin very rapidly to cause damage to liver, kidneys, lungs, and other organs. Concentrated phenol can cause severe skin injury, and if swallowed, results in corrosion of tissues of the upper gastrointestinal tract. There are no data available regarding human health effects of low concentrations of phenol. At concentrations less than 1 percent (1000 ppm) it does not appear to be highly toxic to people, but it imports a characteristic sweet taste to water at approximately 300 ppb.

N-Nitrosodiphenylamine - also called diphenylnitrosamine, belongs to the class of chemicals called nitrosamines. Most nitrosamines are suspected human carcinogens, but there is no evidence that N-nitrosodiphenylamine itself is a carcinogen. In order to possess carcinogenic properties, a nitrosamine must have an alkyl group attached to the nitrogen, and N-nitrosodiphenylamine has two phenyl groups, which can not be metabolized. (Dimethylnitrosamine, which has two methyl [alkyl] groups attached to the nitrogen, is a carcinogen). N-Nitrosodiphenylamine caused liver damage in experimental animals, and should be considered a potential human liver toxin. N-Nitrosodiphenylamine is used in the rubber industry and is also used as a pesticide. N-Nitrosodiphenylamine exists as a powder which is essentially insoluble in water, but soluble in benzene, other organic solvents and gasoline. It is denser than water and does not volatilize.

p-Chloro-m-Cresol - also known as 4-chloro-3-hydroxytoluene or PCMC, is a crystalline solid at ambient temperatures. It is soluble in water, alkali, organic solvents, fats and oils. It will volatilize if heated with steam. p-Chloro-m-cresol is used as a germicide in industry. It is also used as a preservative in the manufacture of glues, gums, paints, inks, textiles and leather goods. Cresols are irritating to skin and mucous membranes. No data on chronic low level exposure are available.

5.4.4 Extractable Organic Chemicals - continued

Naphthalene - a white crystalline solid which sublimes at room temperature, is soluble in benzene, and other organic solvents, but practically insoluble in water. Naphthalene is denser than water. It is widely used as a chemical intermediate. Naphthalene is also used a moth repellant, solvent, fungicide and cutting fluid and in the synthetic tanning industry. Concentrated naphthalene is highly toxic, and ingestion of the concentrated chemical causes nausea and headache, and may lead to liver damage, kidney damage, convulsions and coma. There is no information on health effects of chronic ingestion of small amounts of naphthalene. In very small amounts, however, it does not appear to be toxic.

Fluoranthene - is a crystalline solid, essentially insoluble in water and soluble in benzene. Fluoranthene is a polycyclic hydrocarbon with four rings. It is present in petroleum distillates, and is a common air contaminant. Human toxicity data are not available for fluoranthene. Fluoranthene should be considered toxic to humans, but it is probably not highly toxic in small doses.

Anthracene - is a three-ringed hydrocarbon used in dyes and in the synthesis of many organic chemicals. It is derived from coal tar and exists as a crystalline solid. Anthracene crystals have semi-conducting properties, and are used in the electronics industry. Anthracene is denser than water. Anthracene is a suspected human skin carcinogen. Several compounds which are chemically related to anthracene, such as benz(a)pyrene and benzanthracene are known human carcinogens. Anthracene is an irritant to skin and mucous membranes. There are no human data on effects of chronic ingestion of small doses of anthracene.

Phenanthrene - is an isomer of anthracene and is also derived from coal tar. It is used in the manufacture of dyes, in pharmaceuticals and chemicals. It is a crystalline solid, denser than water and practically insoluble in water. Phenanthrene like its isomer, is a suspected carcinogen. There is no information on long-term ingestion of small amounts of phenanthrene.

Pyrene - is a tetracyclic condensed-ring hydrocarbon derived from coal tar. It is not widely used in industry; its major use is in biochemical research. Pyrene may be a contaminant of other coal tar derivatives. Pyrene crystals are soluble in organic solvents, but are not soluble in water. Pyrene is denser than water. It is a suspected skin carcinogen, but there are no data on human health effects of long-term ingestion.

5.4.4 Extractable Organic Chemicals - continued

4-Nitrophenol - (para-nitrophenol or p-nitrophenol). 4-Nitrophenol exists as yellow monoclinic prismatic crystals, soluble in hot water and organic solvents. 4-Nitrophenol is used as a fungicide in the leather industry and in organic synthesis. 4-Nitrophenol is toxic by ingestion, and high doses have been shown to produce high body temperature (hyperthermia) and methemoglobinemia in laboratory animals. Methemoglobinemia is a condition in which normal hemoglobin is oxidized from the ferrous to the ferric state. The resulting methemoglobin does not carry oxygen adequately. The significance of low level 4-nitrophenol in water cannot be assessed.

Nitrobenzene - is used in chemical syntheses, as a solvent for cellulose ethers and in metal and shoe polishes. Nitrobenzene is slightly soluble in water and soluble in organic solvents. Nitrobenzene is a known human methemoglobin former. The effects of low level environmental contamination with nitrobenzene are unknown.

Phthalate Esters - are used in the plastics industry to increase the flexibility of high polymers. Without the addition of plasticizers, polymers such as polyvinyl chloride (PVC) and cellulose esters would be brittle and would not withstand any external stresses. The phthalate esters are the most widely used plasticizers, and are found in plastics used in construction, automobiles, household products, clothing, toys, packaging and medical devices. Phthalate esters can leach from PVC plastics. They are found in soil, sediment and water samples in every area of the United States. Phthalate esters are not water soluble, but are complexed by humic substances in soil and sediments. These complexes are water soluble, and can be transported in water and sediment.

Phthalates have specific gravities near 1.0. They are stable in the environment, and are soluble in oils and lipophilic material. Phthalate esters have very low acute toxicity in humans. They are used in the manufacture of blood bags, intravenous and urinary catheters and other medical devices without ill effect. They adversely affect the reproduction of several aquatic organisms, and therefore are considered environmental hazards.

Bis (2-Ethylhexyl) Phthalate, also called di-2-ethylhexyl- phthalate or DEPH, is the most abundantly used phthalate ester plasticizer in the high polymer industry. It is a light-colored liquid with a specific gravity of 0.9861 (20°C). DEHP is essentially non-toxic. In large doses, it will cause gastrointestinal upsets in man.

5.4.4 Extractable Organic Chemicals - continued

Di-N-Octyl Phthalate - also called dicapryl phthalate, or DCP, is a colorless, viscous liquid with a specific gravity of 0.965 (25°C). Di-N-octyl phthalate is essentially non-toxic.

Butyl Benzyl Phthalate (BBP) - is an oily liquid with a specific gravity of 1.113 (25°C). Butyl benzyl phthalate has not been implicated in human toxicity.

Di-N-butyl Phthalate (DBP) - is a colorless liquid with a specific gravity of 1.0484 (20°C). Its major use is as a plasticizer, but it is also used as a solvent for oils, and in safety glass, insecticides, printing inks, and paper coatings. Di-N-Butyl phthalate has been suspected of causing central nervous system disorders in high doses. This may be due to the presence of the butyl group and not an indication of phthalate toxicity. There is no information on the chronic human toxicity of di-N-butyl phthalate.

Diethyl Phthalate (DEP) - is a white liquid with a specific gravity of 1.120 (25°C). it is used as a plasticizer and also in insecticides, melting agents, perfumes and mosquito repellants. Diethyl phthalate is a mucous membrane irritant.

5.4.5 PESTICIDES

Several pesticides were detected in groundwater in the Woburn study area. Pesticides are significant in groundwater because, unlike other chemical contaminants found in the environment, they were intended for use as toxic substances and they were, for the most part, intentionally distributed in the environment. Pesticides usually appear in environmental samples as a result of agricultural applications.

BHC - four BHC isomers were detected in groundwater from the study area. BHC is benzene hydrochloride, or more commonly hexachlorocyclohexane. The gamma isomer is the insecticide lindane. Technical BHC contains mixed isomers, with approximately 10-15 percent gamma. Technical mixtures are generally used in agricultural applications; therefore, several BHC isomers can be detected in environmental samples. Lindane (gamma-BHC) is an effective insecticide for flies, cockroaches, aphids, grasshoppers, wire worms and boll weevils. Mixed-BHC is a powder with a specific gravity of 1.87. BHC is insoluble in water, but it is lipid soluble and accumulates in sediments and aquatic organisms; hence it is bio-accumulated in the environment. All BHC isomers accumulate in human tissue, and therefore, any intake may present a potential health hazard.

gamma-BHC (γ-BHC, lindane) - Lindane causes central nervous system damage leading to convulsions and tremors in man upon acute exposure to large doses. Most incidents of lindane

5.4.5 Pesticides - continued

toxicity have occurred in people who were exposed while applying or manufacturing the pesticide, or in children who accidentally ingested the pesticide. Chronic effects of lindane exposure are unknown, but it should be treated with caution because of its ability to bioconcentrate. Lindane has been implicated in blood disorders, but these data are not conclusive. The federal drinking water standard for gamma-BHC is 4.0 ppb. This level cannot be exceeded in public drinking water supplies in the United States. All of the BHC isomers are experimental carcinogens in laboratory animals.

alpha-BHC - (α-BHC) - The alpha isomer of BHC has toxic properties similar to those of lindane.

beta-BHC (β-BHC) and delta-BHC (δ-BHC) - the beta and delta BHC isomers are central nervous system depressants, causing narcosis and dizziness.

DDT and Metabolites-DDT, dichlorodiphenyltrichloroethane, is an insecticide which has not been used in the United States since 1973. DDT is extremely persistent in the environment, and is almost ubiquitous in water, soil and sediments. DDT breaks down in the environment by a series of dechlorination and dehydrochlorination reactions. DDD and DDE are among the breakdown products or metabolites. DDT and its metabolites can be considered together when discussing environmental effects. DDT is soluble in lipophilic sediments and is bioaccumulated in aquatic organisms and mammals, including man. DDT was restricted because of its chronic toxic effects on fish and its ability to interfere with eggshell formation and reproduction in birds. Very little is known about chronic effects of DDT and its metabolites in man. Chronic dosing of animals with high levels of DDT results in liver and kidney injury. DDT is an experimental carcinogen in laboratory animals, but has not been implicated in human cancer.

Heptachlor and heptachlor epoxide - is an organochlorine insecticide belonging to the cyclodiene class of chemicals. Heptachlor epoxide is a metabolic and environmental product of heptachlor. As with most epoxides, heptachlor epoxide is more toxic than the parent compound. Use of heptachlor is restricted because it is a positive carcinogen in laboratory animals. Chronic exposure has been shown to cause liver injury in man and laboratory animals.

5.4.5 Pesticides - continued

Aldrin and Dieldrin - are chlorinated cyclodiene insecticides with similar toxic properties. Because of positive animal carcinogenicity studies, both aldrin and dieldrin have been restricted to non-agricultural applications and are used only for forests and other non-food crops.

Aldrin - causes central nervous system irritability and convulsions in man upon acute exposure to large amounts. Chronic exposure is suspected to cause liver damage.

Dieldrin has toxic properties similar to those of aldrin. No human deaths have been recorded from ingestion of either insectide.

Alpha-Endosulfan - is a sulfur-containing chlorinated hydrocarbon insecticide also known as Thiodan. Endosulfan is a central nervous system poison which causes convulsions in man on acute exposure to high doses. It does not accumulate in human tissue. α-Endosulfan can be used on vegetable crops because of its water solubility and rapid degradation in the environment.

5.4.6 Metals

Excessive concentrations of metals in the environment may occur as a result of their technological and industrial uses or from natural metal deposits. Several metals are naturally present in almost all soil samples and may be present in groundwater and surface water.

Metal toxicology is extremely complex. Several metals are essential for life; others have no effect on human health; still other metals are toxic in small quantities. Some metals, such as selenium, are essential to human health in low concentrations but are toxic in excess. Even iron, which is necessary for normal hemoglobin function, and which is often taken in dietary supplements, can be toxic in excess. In general, chronic effects of ingestion of metals have been characterized and studied to a greater extent than effects of organic chemicals in humans.

5.4.6 Metals - continued

Many metals can be bioconcentrated by humans and aquatic organisms. Several of these metals are non-toxic in small quantities but become toxic when accumulated to a high level in the body. The concept of body burden is important in understanding metal toxicology. Metals are taken into the body daily in food and water. These same metals are excreted from the body through the kidneys or in the feces. The body can only excrete a finite amount of the metal in a twenty-four hour period. As long as the intake of the metal remains lower than the amount which can be excreted, the concentration in the body never builds up to a toxic level, and the person suffers no ill effects. If the metal intake exceeds the amount which can be eliminated, then the excess metal will accumulate in the body. If excess intake continues over time, eventually enough metal to produce toxic effects will be accumulated and toxic symptoms will appear.

Behavior of metals in the environment depends upon the ionic state of the metal, the ionic character of the medium, the pH of the medium, the anions present, the microorganisms present, the properties of associated soils, and several other factors. Sediments are sinks for many metals. Several metals form insoluble sulfides, sulfates and/or hydroxides and precipitate out into the sediments. Other metals form highly soluble complexes which migrate freely in groundwater and surface water.

Lead (Pb) -is one of the most significant environmental contaminant metals. Both the toxicology of lead and its environmental significance have been extensively studied. Lead enters the environment from several sources including manufacture, use, and disposal of storage batteries, cable covering, sheet metal and pipe, solder, fusible lead alloys, typeset metals, and paint pigments. Large amounts of lead enter the environment from use of leaded gasolines and other fuels. When leaded gasolines are burned, lead is discharged to the atmosphere; it enters soil and aquatic systems as fallout in precipitation. Lead forms highly insoluble sulfides which are concentrated in sediments. Typical levels of lead from freshwater sources (surface and groundwater) average less than 10 ppb. Natural lead concentrations in soils and sediments may be in the 10-20 ppm range. Lead affects the central nervous system, peripheral nervous system, kidney, gastrointestinal tract and blood-forming organs. The toxicology of lead has been studied in detail. Lead is a cummulative poison and most lead poisoning is a

5.4.6 Metals - continued

result of chronic exposure. Acute effects are seen only upon exposure to massive doses. Daily intake of lead from food and water is approximately 0.3 mg. in the average American diet. The body burden level in a 70 kg. man is approximately 120 mg. Chronic exposure to levels in excess of 0.3 mg/day will lead to an accumulation of potentially toxic levels. This report will summarize the most important aspects of lead toxicity.

Central nervous system - effects of lead poisoning are generally noted in people chronically exposed to large amounts of lead. There is actual structural and cellular damage to the brain, resulting in symptoms which may range in severity from restlessness and headaches to convulsions, coma and death. Children, especially young infants, are at increased risk to this "lead-induced encephalopathy".

Peripheral nervous system - consists of the nerves which are outside of the brain and the spinal cord. Effects of lead toxicity on the peripheral nervous system are muscle weakness and sensory disturbances such as lack of feeling in an arm or leg. These effects are usually reported in workers such as painters who are exposed to high levels of lead over long periods.

Kidney - Chronic lead exposure damages kidney tubules resulting in loss of essential nutrients such as glucose, amino acids and phosphate in the urine.

Gastrointestinal tract - Chronic lead exposure can cause loss of appetite, nausea, vomiting, diarrhea and/or constipation, loss of weight and a metallic taste in the mouth.

Blood-forming organs - Lead interferes with synthesis of hemoglobin and affects the membranes of red blood cells,. resulting in anemia. The anemia of lead poisoning is not usually severe, but is often a first indication that a person has been exposed to potentially hazardous levels of lead. lead-induced anemia is characterized by a condition called basophilic stippling in which the mature red blood cells contain remnants of nucleic acids from the nucleus of the immature red cell. This condition is often diagnostic of lead poisoning. Lead is a regulated chemical in public water supplies in the United States. The federal Maximum Contaminant Level (MCL) for lead is 50 ppb. This is a level which, if ingested daily, is not expected to produce injury. The MCL for lead takes ingestion of lead from sources other than water into consideration.

5.4.6 Metals - continued

Cadmium (Cd) - and cadmium compounds are used in electroplating and electro-dipping operations, and in alloys, electrical equipment, storage batteries (Ni-Cd), power transmission wire, TV phosphors, photography, lithography, pigments, inks, and in many other industrial uses. Cadmium occurs naturally as cadmium sulfide in lead, copper and zinc ores. Cadmium is a byproduct of smelting operations for these metals and is emitted as vapor from smelters. Natural soil concentrations of cadmium are less than 1 ppm. Sewage sludge is often contaminated with cadmium, and cadmium may enter surface and groundwater when leached out of sewage sludge used as fertilizer on agricultural land. Background cadmium concentrations in natural waters are usually in the range of 1-5 ppb.

Cadmium, like lead, has been extensively studied in man. Long term, low-level ingestion of cadmium has been found to contribute to degeneration of bone. Other human health effects have been associated with chronic cadmium exposure. Kidney damage has been reported after heavy industrial exposure. (Inhaled cadmium fumes and dusts have an effect on lung function, but this type of health damage is not pertinent to water exposure.)

The kidney effects of cadmium poisoning consists of damage to the renal tubules which results in loss of protein, sugar, amino acids, calcium, and uric acid in the urine. Degenerative bone disease associated with cadmium intake appears to result from both increased cadmium intake in food and water and calcium deficiency. Loss of calcium in the urine because of cadmium toxicity exacerabates the condition. Other cadmium induced effects are yellowing of the teeth after chronic heavy exposure.

The approximate body burden for cadmium is 30 mg/70kg man. People normally take in up to 0.2 mg cadmium per day in the diet, mostly from shellfish, liver and kidney. Cigarette smokers may be exposed to cadmium which is present in cigarette smoke. Cadmium concentration in drinking water is regulated through the Safe Drinking Water Act. The Maximum Contaminant Level for cadmium in public water supplies is 10 ppb.

Arsenic (As) - is not a metal, but belongs to the class of elements called semiconductors. Arsenic is grouped with the metals for toxicological discussions. Arsenic is naturally occurring in most soils, and is present in relatively high concentrations in seafoods, liver, and pork. Many ocean fish require arsenic as

5.4.6 Metals - continued

an essential mineral for energy metabolism, in much the same way that mammals require phosphorus. Most naturally occurring arsenic in the environment is in the pentavalent oxidation state (As^{+5}). Arsenic which enters the environment from industry tends to be trivalent arsenic (As^{+3}). Pentavalent arsenic forms arsenates which are not generally toxic. Arsenates are rapidly excreted by the kidneys with no physiologic effect. Trivalent arsenic forms arsenites, which are toxic. Arsenic and arsenic-containing compounds (arsenicals) are used in alloys, weed killers, insecticides, wood preservatives, anti-fouling paints, and for many uses in the solid state electronics industry.

Arsenicals undergo many reactions in soils and sediments. They can be oxidized, reduced, and/or methylated by naturally-occurring micro-ogranisms. Arsenicals have a high affinity for ferrous and aluminum oxides in natural soil. They are adsorbed to soil particles, acted upon by micro-organisms to form less strongly-adsorbed compounds, and subsequently desorbed from the soil. Arsenic in soil may be reduced to arsine or methylarsine which are volatile and escape into the air environment. Arsenic tends to accumulate in benthic sediments.

If ingested, arsenic in the arsenite form will bind to tissue proteins. The arsenites are thus accumulated in protein in liver, skin, muscle and hair. chronic ingestion of large amounts of arsenic results in fatigue, gastrointestinal upset and anemia. There is some evidence that long-term contact with trivalent arsenic in industry and agricultural application is related to skin and lung cancer. Trivalent arsenic should be treated as a possible human carcinogen, although the carcinogenic potential of arsenic and arsenicals in drinking water is not fully characterized. Studies of people exposed to trivalent arsenic suggest that it may also be implicated in the development of goiters.

The body burden for arsenic is estimated at approximately 100 mg for a 70 kg. man. Estimated daily intake from food and water is 0.7 mg. The Maximum Contaminant Level for total arsenic in United States public water supplies is 50 ppb. This number is based on the potential cummulative toxic effects of trivalent arsenic, but the standard includes levels of pentavalent arsenic because there is no simple way to differentiate the valence states.

5.4.6 Metals - continued

Mercury (Hg) - is a silvery, liquid metal with a specific gravity of 13.6 Mercury and its compounds are used as bactericides, fungicides, and in amalgams, instruments (barometers, thermometers) and electrical apparati. Mercury cells are used in the production of chlorine and caustic soda from soda lime. Mercury is a common fungicide used in anti-fouling paints and in the pulp and paper industry.

The environmental distribution and human toxicology of mercury depend upon the form in which it is present.

Elemental mercury (Hg°) is rarely an environmental problem. It is an important toxicological problem in industry because of its high vapor pressure. Mercury vapor is toxic to the central nervous system. Elemental mercury is soluble in water (20 ug/l) and thus could be distributed in the environment, but ingestion of elemental mercury does not constitute a serious toxic hazard.

Inorganic mercury exists in two oxidation states, mercurous ion (Hg^{+}) and mercuric ion (Hg^{++}). The mercuric ion is highly water soluble and much more toxic than the mercurous ion. Inorganic mercury compounds can be transported in the environment in surface runoff. They can be complexed to organic and inorganic particles in soil and to sediments, especially those with high humic acid content, or with high sulfur content. Mercuric sulfide (HgS) is an extremely stable form of mercury and sediments high in sulfur function as mercury sinks. Mercury which is complexed to organic material such as humic acid is available for transport. Inorganic mercury in sediments can be transformed to organic mercury by microorganisms which are able to biomethylate mercury. Methyl mercury and other organic mercury compounds are not bound to sediments.

Inorganic mercury is primarily a kidney toxin and causes loss of protein in the urine, which can result in systemic protein deficiency.

Organic mercury is by far the most toxicologically and environmentally significant form of the metal. Organic mercury may be discharged directly to the environment in waste from the pulp and paper industry, or it may form in the environment as a result of methylation in sediments.

5.4.6 Metals - continued

The major target of organic mercury is the central nervous system. A classic case history of methyl mercury poisoning exists. Between 1953 and the middle 1960s, over 1200 cases of organic mercury toxicity were reported in the area surrounding Minamata Bay in Japan. The Minamata incident resulted from discharge of mercury compounds from an industry. The mercury compounds were assimilated by microorganisms and then by larger organisms which were in turn consumed by fish. The fish were eaten by people in the Minamata Bay area.

Effects seen in people with so-called Minamata disease included tremor, incoordination, paralysis and pathological reflexes. Because organic mercury can cross the placental barrier, physical defects and mental retardation were seen in children born to women with Minamata disease. The average daily intake of mercury in the United States diet is approximately 20 ug, mostly from fish. Average United States groundwater concentrations of mercury are below 1 ppb. The Maximum Contaminant Level for mercury in public drinking water supplies is 2 ppb.

Chromium (Cr) - Chromium is a metal used in steel fabrication, leather tanning and paint and pigment formulations. Chromium exists in six valence states but only trivalent (Cr^{+3}) and hexavalent (Cr^{+6}) chromium are biologically and environmentally significant. Chromium forms water soluble hydrated complexes which can be transported through environmental media as well as insoluble sulfates which may concentrate in sediments. Average concentrations of chromium in natural water are below 10 ppb. Chromium intake through food, especially brown sugar, butter and other animal fats, has been estimated at 30 to 100 ug./day.

Trivalent chromium compounds are relatively non-toxic. Trivalent chromium has been implicated in contact dermatitis in industry, but it is probably not an environmentally significant toxin. Hexavalent chromium compounds have been associated with lung cancer in industry in people who are exposed to chromic acid or chromate dusts or fumes. People exposed to airborne chromium in industry also have an increased incidence of skin ulcerations, perforation of the nasal septum and throat and liver inflammation.

There is no indication that ingestion of chromium at environmental concentrations in food and water has had any adverse effect on human health. In one animal experiment, mice who drank water containing 5 ppm (5000 ppb) hexavalent chromium

5.4.6 Metals - continued

over their lifetimes developed more cancers than mice exposed to similar amounts of trivalent chromium or to no chromium but there is no indication that ingestion of chromium causes human cancer. The current Maximum Contaminant Level for chromium in the United States public water supplies is 50 ppb as Cr^{+6}.

Aluminum (Al) - is a widely used industrial metal which occurs naturally in bauxite ores. Aluminum is the most abundant metal in the earth's crust and the third most abundant element. It does not occur in the free state in nature. Aluminum and its compounds are used in textiles, printing, leather tanning, paper sizing, waterproofing, pigments, pharmaceuticals and cosmetics. Aluminum compounds are also used as catalysts and intermediates in a variety of synthetic chemical processes.

Aluminum compounds are not very stable in the environment. Aluminum forms soluble sulfates but the sulfide reacts with water to evolve hydrogen sulfide. Aluminum compounds can form hydrated complexes which can be transported in the environment.

Aluminum is essentially non-toxic. The human body burden is over 100 mg and daily intake of aluminum from food, water and cooking vessels appears to have no effect on human health. There are no recommended limits for aluminum in drinking water.

Barium (Ba) - is used in the manufacture of alloys, paints, paper, soaps, glass and ceramics. Barium carbonate and barium fluorosilicate are used as insecticides. Barium sulfate, an insoluble and radiopaque compound, is used in diagnostic radiology. Barium compounds and complexes are abundant in nature and natural water may contain barium from natural sources.

Barium found in water samples results from dissociation of soluble barium compounds. Barium ion is toxic on ingestion and, if ingested in large doses, may cause gastrointestinal disturbances, muscular paralysis and cardiac irregularities. Barium is excreted from the body rapidly and is not accumulated. Daily intake of barium is approximately 16 mg/day, mostly from vegetables which can accumulate barium from the soil. The Maximum Contaminant Level for barium in the United States drinking water supplies is 1.0 ppm (1000 ppb).

Barium sulfate is not absorbed by the human body and is not toxic.

5.4.6 Metals - continued

Beryllium (Be) - is used in the manufacture of several alloys for use in non-sparking implements and nuclear reactors. It is also used in the electronics industry. Beryllium is naturally present in some coal deposits and the burning of coal is the single largest source of environmental beryllium contamination.

Beryllium is a known industrial chemical hazard. Inhalation of beryllium causes a chronic lung disease called berylliosis, and long-term skin contact leads to dermatitis and skin ulceration. Ingested beryllium, however is poorly absorbed by the gastrointestinal tract and may not be responsible for human disease.

Cobalt (Co) - is an essential element in mammalian nutrition. It is contained in vitamin B_{12}, which is essential for the prevention of pernicious anemia. Cobalt deficiency is related to anemia, weight loss and retarded growth.

Excessive cobalt ingestion results in production of excess numbers of red blood cells, a condition known as polycythemia. Excess cobalt intake may produce vomiting, diarrhea and goiter. Cobalt has been reported to have adverse effects on heart muscle, leading to congestive heart failure. This effect was reported after a Canadian beer company added 1 ppm (1000 ppb) cobalt to beer to enhance its foaming qualities. Researchers who investigated the incident suggested that the combination of cobalt and alcohol may have been synergistic in producing heart muscle damage.

Average daily cobalt intake in the United States diet is approximately 0.3 mg., mostly from water and vegetables. Cobalt is used therapeutically in treatment of pernicious anemia and sickle cell anemia, and in low concentrations is essentially non-toxic.

Copper (Cu) - and its compounds are used in wiring, pipes, alloys, machinery, insecticides, dyes and pigments, and in many other industrial applications. Copper is widely distributed in nature and is contained in natural waters and foods. Copper is an essential element needed for the function of several enzyme systems. It is generally accepted that excess copper in the diet is non-toxic to man, although one study has suggested that long term excess dietary copper may be one factor in the development of atherosclerosis.

5.4.6 Metals - continued

Copper is regulated at 1 ppm (1000 ppb) in the United States public water supplies because, above this level, copper adds adverse taste and color to water. There is no human health significance to this level.

Iron (Fe) - is used in several industries. Iron is an essential element required for the formation of hemoglobin and various enzymes. It is widely used in medicine and as a food additive. Iron is present naturally in water, soil and foods.

Chronic excess iron intake can cause damage to the liver and changes in the blood. Excess iron intake is usually a result of over-medication with iron supplements. Iron toxicity from environmental iron is unlikely. Iron imparts a "rusty" color and an unacceptable taste to water at levels over 1 ppm (1000 ppb) and, although this level of iron contamination is not toxic, the water is esthetically unacceptable. The secondary (non-health related) Maximum Contaminant Level for iron in the United States public water supplies is 300 ppb because of odor, color and taste which may occur at higher levels.

Nickel (Ni) - The main industrial uses of nickel are in the manufacture of batteries, steel alloys and electronics components. Nickel is used in the food processing industry especially in the production of gelatin and baking powder. Large amounts of nickel are found in vegetables, legumes, and grains. Daily intake of nickel has been estimated at approximately 0.5 mg.

The toxicity of excess dietary nickel is unknown. Inhalation of nickel carbonyl, a compound formed by nickel compounds in the presence of carbon monoxide, has been implicated in lung and nasal cancer.

Manganese (Mn) - is used in alloys, batteries, ceramics, glass, matches, fertilizers, dyes, and animal feed additives. Manganese compounds are also used as germicides. Manganese intake from food is approximately 5 mg/day. It is an essential element necessary for enzyme function. Vegetables, grains, tea, fruits and nuts are good dietary sources of manganese.

Large doses of manganese salts can cause gastrointestinal irritation. Chronic inhalation of manganese dioxide in industrial situations has been known to cause neurological disturbances. This type of exposure cannot be compared with ingestion of manganese. Many grains and cereals contain over 100 ppm manganese and apparently do not precipitate toxic effects in man or animals.

5.4.6 Metals - continued

Manganese salts form highly insoluble hydrated complexes in water, resulting in abnormal color at low concentrations. The secondary Maximum Contaminant Level for manganese based on esthetic qualities of drinking water, is 50 ppb.

Zinc (Zn) - is used in wood preservatives, glass, paper, galvanizing processes, pigments for white paint, rubber, glazes and enamels.

Zinc is usually found in combination with cadmium in the natural state. Zinc is almost ubiquitous in nature, and is naturally present in water, soil and air. Zinc is found in seafood, meat, grains, milk, cheese, eggs, nuts and legumes. It is an essential human nutrient required for the function of several enzymes. The average American diet contains 12.6 mg/day zinc.

Ingestion of concentrated zinc salts causes gastroenteritis. Other effects of excess ingested zinc are unknown.

Because of objectionable taste, odor and color, zinc is regulated at 5 ppm (5000 ppb) in United States drinking water.

Boron (B) - is a non-metallic element in Group IIIA of the Periodic Table. it is used in alloys, welding and soldering, water softeners, soaps, glass, pottery and enamel. Boric acid is a useful antiseptic. Boranes are used in high energy fuels and in rubber vulcanization processes.

Average daily intake of boron from vegetables and natural waters is between 10-20 mg. Boron poisoning has been known to occur in people who apply large amounts of boric acid to cuts or burns. The boric acid is absorbed through the skin and causes central nervous system depression and gastroenteritis. Ingestion hazards of excess boron in drinking water are not known.

Vanadium (V) - compounds are used in the manufacture of sulfuric acid, pigments, insecticides and photographic chemicals. Vanadium has a high affinity for lipids and is present in dietary fats and oils. It is present in natural waters in the range of 1-10 ppb. There is some evidence that vanadium may be an essential human nutrient, and may function in formation of blood and in prevention of dental caries.

5.4.6 Metals - continued

Dietary vanadium is stored in the fat. Ingestion of vanadium in large doses can cause gastroenteritis and kidney injury, but such poisoning incidents have been attributed to over-medication with vanadium compounds. In industry, vanadium dust and fumes are recognized respiratory hazards. There is no evidence that excess dietary vanadium is highly toxic.

Antimony (Sb) - is used in storage batteries, alloys, pewter, rubber, matches, textiles, ceramics, enamels, lacquers and paints. Antimony is used in the manufacture of tinfoil and can leach from tinfoil wrapping into food. Antimony compounds were formerly used in medicine to treat parasitic disease, but this use has been abandoned because of toxicity.

Very little toxicity data are available for antimony other than information from studies of medical usage of antimonials. Symptoms of overdose include vomiting, diarrhea, respiratory difficulties and collapse. Environmental antimony poisoning has not been documented.

Selenium (Se) - Selenium is a non-metal semi-conductor used in the electronics industry, in solar batteries, glass, ceramics, steel manufacturing, paints, and varnishes, insecticides, fungicides and antidandruff agents.

Selenium is considered an essential element, and selenium deficiency results in multiple symptoms in animal studies. Selenium is naturally present in seafood, meat and grains. Selenium is found in human milk. Natural waters contain an average of 20 ppb selenium.

Industrial respiratory exposure to selenium compounds causes eye and nasal irritation and possibly liver damage. Excess ingestion of selenium has been documented in livestock. Dietary levels of 100 to 1000 ppm in food resulting from animals grazing in selenium-containing crops have caused visual impairment, weakness of limbs and respiratory problems. In man, symptoms of selenium toxicity include gastrointestinal disturbances, partial hair and nail loss, and discolored teeth. There is some evidence, however, that people who ingest foods which contain some selenium have lower cancer death rates than people who have little or no selenium in the diet.

The Maximum Contaminant Level for selenium in public drinking water is 10 ppb.

5.4.6 Metals - continued

Tin (Sn) - is used in food packaging, solder and alloys. Inorganic tin compounds are used in dyes for textile and cosmetics (toothpaste contains stannous chloride). Organic tin compounds are used as fungicides, bactericides, and slimicides.

Average United States food intake of tin is approximately 17 mg/day. Most of this tin comes from food processing and packaging. There appears to be little effect of human health from inorganic tin intake from dietary sources.

Organic tin compounds are much more toxic than inorganic tin. Excessive intake of organic compounds results in brain and central nervous system damage. Most evidence of organic tin poisoning is from incidents of food contamination and not from environmental exposures.

Thallium (Tl) is used in electronics, alloys, optical lenses, dyes and pigments. It is contained in iron, cadmium and zinc ores and may be a byproduct of processes which use these metals. Thallium has been used as a rat poison, but this use was restricted in 1972.

Chronic thallium poisoning results in hair loss, gastroenteritis, lung damage, kidney damage and central and peripheral nervous system injury. Cases of poisoning usually result from contamination of food or use of thallium salts as dipilatories.

Magnesium (Mg) - is a light metal used in alloys, photography, and in the chemical industry as a catalyst and reducing agent. Magnesium is naturally occurring in seafood, cereals, nuts and meats. The average level of magnesium in finished water is approximately 6.5 ppm (6500 ppb). This level varies with water hardness; hard water contains high levels of magnesium. Magnesium is essential in human nutrition.

Magnesium may be ingested in large quantities without ill effect. Magnesium hydroxide (milk of magnesia) is a universal antidote for oral poisoning. The citrate, oxide, sulfate, hydroxide and carbonate are used as antacids or as laxatives.

People with kidney disease can suffer adverse effects to high levels of magnesium, but in normal individuals dietary and therapeutic magnesium is rapidly cleared through the kidneys and toxicity is rare.

5.4.6 Metals - continued

Calcium (Ca) -is an alkaline earth element which does not occur free in nature. Calcium compounds are extremely abundant in nature, however, and are widely used in industry, agriculture and medicine. Calcium is an essential human nutrient, and calcium deficiency states are well known in medicine. Calcium is present in foods and natural waters and is considered non-toxic.

Sodium (Na) - is also an alkaline earth element. Like calcium, sodium does not occur in nature in the free state, but sodium salts are ubiquitous in soil, sediments and water. Sodium is an essential element in the human diet. There is evidence linking excess sodium intake with increased incidence of hypertension (high blood pressure). Both federal and Massachusetts guidelines recommend sodium levels of no higher than 20 ppm (20000 ppb) in public drinking water.

There is no evidence that sodium causes high blood pressure. Sodium affects the kidney's ability to regulate water and electrolyte balance in the body. These renal and electrolytic disturbances are more pronounced in people with high blood pressure or who have a tendency to develop high blood pressure. The presence of high levels of sodium in food or water will worsen the tendency to hypertension in people with kidney or heart disease, or who are prone to these diseases.

5.5 SUMMARY

Several organic and inorganic chemicals included on the EPA list of 129 Priority Pollutants have been identified in Woburn groundwater. The presence of chemical contaminants in groundwater raises the possibility that drinking water from the aquifer may have been contaminated in the past of may become contaminated in the future.

Prediction of potential human health effects which may result from contamination of the drinking water supply is difficult because very little information describing human health effects of chronic ingestion of low level chemical contaminants exists. The best source of data on toxicity of environmental contaminants comes from animal experimentation in which laboratory animals are fed specific chemicals daily over their lifetimes. Information obtained from these studies is very useful in determining which organ systems are particularly vulnerable to the chemical insult. These experiments are not always accurate in predicting

5.5 Summary - continued

how man will respond to a particular chemical, and how much of the chemical is required before a human will get sick. Often, the levels of chemicals used in animal experiments may be unrealistic in terms of human experience. High levels of chemicals are used in animal studies because, with high exposure levels, scientists are more likely to see toxic effects in experiments in which a relatively small number of animals is used. Animal studies in which large doses of chemicals are used also present a problem in defining which substances are carcinogens, or tumor-inducing agents. Many substances appear to be able to induce tumors in animals when given in large doses over the animals' lifetimes.

Most of these substances have been used by people in industry over several years and do not appear to be associated with human cancer. Many scientists believe that tumors are the result of a toxic response which occurs when a "threshold dose" of the toxic chemical is exceeded. This theory assumes that cancer is similar to other toxic responses in this respect: there is a dose below which toxicity is not seen and above which adverse health effects appear. There is, however, another theory on the induction of cancer which contradicts the "threshold" model. The "one-hit" model assumes that if a chemical can cause cancer at a high exposure level, then it can also cause cancer at a low exposure level. The only difference is that it becomes more likely statistically that a high dose will cause cancer. There are several other theories which attempt to explain possible causes and origins of cancers; none of the theories can completely explain or disclaim suspected associations between environmental chemicals and human cancer. Most scientists who study cancer agree that most human cancers result from a combination of factors including environment, lifestyle, heredity and nutrition. Although several chemical and physical agents have been identified as human carcinogens, among them vinyl chloride, asbestos and ionizing radiation, most chemical substances which have caused tumors in laboratory animals can only be labeled "suspected carcinogens" in man. Until more data on actual human exposure to chemicals are obtained, the association between these "suspected carcinogens" and cancer remains tentative.

5.5 Summary - continued

The chemical analyses performed as part of the Woburn groundwater study should be used to identify potential sources of contaminants. This information, combined with data obtained from the study and assessment of the behavior of the individual chemical contaminants in the environment, may be used to identify particular areas of future concern within the City of Woburn.

This section does not attempt to identify past or present human health hazards or predict future problems in the City of Woburn. None of the samples analyzed in this study were collected from wells presently furnishing public drinking water. Determination of whether or not the Woburn drinking water supply has been or will be compromised by the presence of chemicals in the groundwater is beyond the scope of this discussion. This discussion is intended to provide an assessment of potential health effects which may be noticed in the event that the drinking water supply becomes contaminated.

SECTION 6 - REFERENCES

1. Tufts University, Department of Urban and Environmental Policy. Hazardous Wastes in Woburn. Prepared for the Reading, Massachusetts Conservation Commission under a grant from the Fund for the Improvement of Post Secondary Education #6007804773. Medford, Massachusetts. May 1980. pp 1-15.

2. Geotechnical Engineers, Inc. Report on Groundwater and Surface Water Study - Stepan Chemical Company, Wilmington, Massachusetts. Prepared for the Commonwealth of Massachusetts, Water Resources Commission, Division of Water Pollution Control. Project 77348. Winchester, Massachusetts. 6 December 1978. pp. 1-9

3. Fred C. Hart Associates, Inc. Plan for Investigation of Hazardous Waste Problems: Woburn, Massachusetts. Prepared for the Commonwealth of Massachusetts and U.S. Environmental Protection Agency (Contract No. 68-01-5815). New York, New York. March 1980. pp 1-16.

4. Memo from Cleary, Robert, Massachusetts DEQE, Woburn, Massachusetts. 23 April 1979. 10 pp. Notes relative to Janpet property and D'Annalfo Property, North Woburn, Massachusetts.

5. Cook, D. K. Site Inspection Reports for E. C. Whitney and Sons, Whitney Barrel Company, Ritter Trucking Company, Raffi & Swanson, Inc., MDC Septage Receiving Station, New England Resins and Pigments, Woburn Steel Drum, Inc., and Woburn Sanitary Landfill. EPA FIT Project. TDD F1-8006-01. 28 August - 17 September 1980.

6. Cook, D. K. Site Inspection Reports for Severence Trucking Company, Inc., Aberjona Auto Parts, John J. Riley Company, Whitney Barrel Company, Atlantic Gelatin and Independent Tallow Company. EPA FIT Project. TDD F1-8005-01E. 20 November - 17 December 1980.

7. Cook, D. K., Inventory and Analysis of Existing Well Data for East and North Woburn, Massachusetts. EPA FIT Project. TDD #F1-8010-03. 9 January 1981. p. 1-19.

8. Ecology and Environment, Inc. Interim Report on the Geology and Groundwater of North and East Woburn, Massachusetts. EPA FIT Project. TDD #F1-8010-02A/03A. 3 April 1981.

6. References - continued

9. Brantner, K. A., R. B. Pajasek, and E. L. Stover. Priority pollutants, Part 2: analytical testing. Pollution Engineering. April 1981. p. 30-32.

10. Hammond, P. B. and R. P. Beliles. Metals. in Toxicology, Second Edition. J. Doull, C. D. Klaassen and M. O. Amdur, eds. MacMillan Publishing Co., Inc. New York. 1980.

11. Schroeder, H. A. The biological trace elements. J. Chronic Disease. 18: 217. 1965.

12. Schroeder, H. A. Cadmium as a factor in hypertension. J. Chronic Disease. 18: 647. 1965.

13. Kanisawa, M. and H. A. Schroeder. Lifetime studies on the effects of trace elements on spontaneous tumors, in mice and rats. Cancer Res. 29: 892. 1969.

14. U.S. Public Health Service. Community Water Supply Study Analysis of National Survey Findings. U.S. Department of Health, Education and Welfare, Washington, D.C. 1970.

15. Schroeder, H. A. et al. Essential metals in man. Magnesium. J. Chronic Disease 21: 815. 1969.

16. Sax, N. I. Dangerous Properties of Industrial materials, Fifth Edition. Van Nostrand/Reinhold Company. New York. 1979.

17. Hawley, G. G. ed. The Condensed Chemical Dictionary, Ninth Edition. Van Nostrand Co. New York. 1977.

APPENDIX A

Analytical Data

Tabulated by Sampling Location

TABLE 1

Results of the Inorganics Analyses of Thirty (30) Groundwater Samples
from East and North Woburn, Massachusetts
(concentrations in ppb unless otherwise noted)

Well #	Al	Cr	Ba	Be	Cd	Co	Cu	Fe (ppm)	Pb	Ni	Mn	Zn	B	V	Ca (ppm)	Mg (ppm)	Na (ppm)	As	Sb	Se	Tl	Hg	Sn
6	--	--	19	--	--	--	--	0.5	--	--	410	--	85	--	33	6.8	72	--	--	--	--	--	--
364	980	53	225	--	17	44	95	115	1460	--	3250	188	94	--	47	7.7	70	--	--	--	--	--	--
419	140	--	44	--	--	--	--	0.066	270	--	420	13	210	20	41	7.5	25	--	--	--	--	1.1	79
420	--	--	20	--	--	--	--	0.18	--	--	1300	--	--	--	38	8.1	40	--	--	--	--	--	--
424	--	--	--	--	--	--	--	25	--	--	320	--	--	--	8	1.6	18	--	--	--	--	--	--
426	8800	30	50	--	--	10	20	101	--	20	710	1320	20	--	10	3.3	10	--	--	--	--	--	300
436	160	--	110	--	--	--	23	0.03	--	--	130	190	180	36	55	11	36	--	--	--	--	1.2	100
439	--	--	83	--	--	--	--	0.13	--	--	1200	43	108	--	70	9.9	220	--	--	--	--	--	--
AG1	--	--	30	--	--	--	--	3.9	40	--	30	240	30	--	34	4.4	47	--	--	--	--	--	--
AG2	--	--	40	--	--	--	20	0.16	--	--	130	350	40	--	38	5.6	44	--	--	--	--	--	--
AG5	--	--	60	--	--	--	--	0.08	50	--	240	40	40	--	60	8.3	49	--	--	--	--	--	--
AG6	--	--	150	--	--	--	--	2.1	--	--	1120	50	180	--	74	10.5	46	--	--	--	--	--	--
AG7	--	--	30	--	--	--	--	1	40	--	300	20	40	--	30	6.4	46	--	--	--	--	--	--
E3	--	--	10	--	--	--	220	0.56	--	--	170	12200	--	--	56	4.7	18	--	--	--	--	--	--
E8	140	--	35	--	--	--	150	0.09	--	--	150	520	260	19	60	10	17	--	--	--	--	2.4	84
E9	130	--	42	--	--	--	21	0.03	--	--	83	24	270	32	120	13	57	13	--	87	--	--	180
E11	--	--	10	--	--	--	60	0.5	--	--	20	180	--	--	47	9.5	40	--	--	--	--	--	--
E11A	--	--	20	--	--	--	60	0.08	--	--	--	50	--	--	42	7.9	37	--	--	--	--	--	--
E25	--	--	60	--	--	--	--	5	--	20	12500	30	3170	30	81	13	69	30	--	--	--	--	--
E26	86	--	11	--	--	--	--	1.4	--	--	110	5500	180	15	10	2.3	3.2	--	--	--	--	1.1	31
E27	150	--	12	--	--	--	67	4.9	--	28	780	150	230	22	40	7.3	28	--	--	--	--	--	110
E37	26500	60	180	--	--	20	60	118	40	40	940	2440	40	--	14	9.3	19	30	--	--	--	--	30
E38	106	10	40	--	--	--	20	51	560	--	250	540	10	--	18	2.3	24	--	90	--	--	--	--
E39	12300	30	150	2	5	20	140	637	--	20	1300	1400	50	--	25	9.2	46	90	--	--	--	49	--
GW5	579	142	19	--	--	12	--	1.7	--	--	920	43	61	--	46	7.0	295	--	--	--	--	--	--
GW10	4790	32	259	--	--	--	--	0.2	--	--	220	72	--	--	7.6	3.1	90	--	--	--	--	--	--
GZ2	304000	890	920	--	40	200	11500	365	4550	360	2550	14600	120	640	245	32	40	2000	--	--	30	2	--
GZ3	274000	290	2160	--	--	250	980	475	--	200	17200	1360	100	550	513	95	260	100	--	--	--	--	--
GZ5	362000	2070	1480	--	--	110	47800	269	3880	280	1500	17400	80	570	203	46.9	37	7000	--	--	50	2	--
GZ6	70200	340	80	--	5	60	1220	380	80	100	1850	5150	240	250	115	30.5	142	1000	--	--	10	2	--

(--) = Not detected

TABLE 2

Results of the Organic Analyses of Thirty-two (32) Groundwater Samples from East and North Woburn, Massachusetts
Semi-Volatile Organics
(concentrations in ppb)

Well #	p-Chloro-m-cresol	4-Nitrophenol	Phenol	Fluoranthene	Naphthalene	Nitrobenzene	N-Nitrosodi-phenylamine	Bis(2-ethylhexyl) phthalate	Butyl benzyl phthalate	Di-n-butyl phthalate	Di-n-octyl phthalate	Diethyl phthalate	Anthracene	Phenanthrene	Pyrene
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
364	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
419	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
420	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
424	--	--	--	--	--	--	--	310	--	--	--	--	--	--	--
426	--	--	57	--	--	--	<10	35	--	--	<10	<10	--	--	--
436	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
439	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AG1	--	--	--	--	--	--	--	<10	--	--	<10	<10	--	--	--
AG2	--	--	--	--	--	--	--	<10	38	--	<10	<10	--	--	--
AG4A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AG5	--	--	--	--	--	--	--	<10	--	--	<10	<10	--	--	--
AG6	--	--	--	--	--	--	--	<10	--	--	<10	<10	--	--	--
AG7	--	--	--	--	--	--	--	<10	--	--	<10	--	--	--	--
E3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E11A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E25	--	--	39	--	--	--	--	--	<10	39	--	--	--	--	--
E26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E37	35	--	266	--	36	--	--	<10	--	--	<10	<10	--	--	--
E38	--	--	132	--	--	--	--	2650	--	38	--	--	--	--	--
E39	--	--	--	21	--	--	--	771	--	83	--	--	--	--	--
GW2	--	2831	198	--	--	2669	275731	62524	--	4226	--	--	--	--	--
GW5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GW10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GZ2	--	--	--	14	--	--	--	--	--	--	--	--	<10	<10	<10
GZ3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GZ5	--	--	--	--	--	--	--	--	--	<10	--	--	--	--	--
GZ6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 2 - continued

Results of the Organic Analyses of Thirty-two (32) Groundwater Samples from East and North Woburn, Massachusetts
Volatile Organics
(concentrations in ppb)

Well #	Benzene	Carbon tetrachloride	Chlorobenzene	1,2-Dichloroethane	1,1,1-Trichloroethane	1,1-Dichloroethane	Chloroform	1,1-Dichloroethylene	1,2-trans-dichloroethylene	Ethylbenzene	Methylene chloride	Trichlorofluoromethane	Tetrachloroethylene	Toluene	Trichloroethylene
6	--	--	--	--	133	--	--	--	116	--	--	--	28	--	1372
364	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
419	<10	--	--	--	--	--	--	--	14	--	--	--	36	--	210
420	<10	--	--	--	<10	--	--	--	21	--	--	--	41	--	73
424	--	--	--	--	--	--	--	--	<10	--	22	--	--	<10	<10
426	<10	--	--	--	--	--	--	--	--	--	16	--	--	63	<10
436	<10	--	--	--	--	--	--	--	<10	--	--	--	12	--	12
439	--	--	<10	--	28	--	--	--	12	--	--	--	--	--	53
AG1	--	--	--	--	<10	--	<10	--	--	--	16	--	--	75	<10
AG2	--	--	--	--	<10	<10	<10	<10	<10	<10	12	<10	--	--	<10
AG4A	--	--	--	--	67	15	--	20	91	--	--	--	--	--	2290
AG5	--	--	--	--	55	25	--	<10	17	--	13	--	<10	<10	91
AG6	--	--	--	--	70	<10	--	<10	15	<10	18	102	--	<10	76
AG7	--	--	--	--	<10	<10	--	--	<10	<10	<10	--	--	13.7	10
E3	<10	--	--	--	--	--	<10	--	--	--	--	--	--	--	<10
E8	<10	--	--	--	--	--	--	--	--	--	--	--	--	--	<10
E9	<10	--	--	--	--	--	--	--	--	--	--	--	--	--	--
E11	<10	--	--	--	<10	--	--	--	210	--	--	--	89	--	280
E11A	<10	--	--	--	<10	--	--	--	120	--	--	--	63	--	160
E25	<10	--	--	--	611	<10	<10	--	--	--	13	775	<10	45	135
E26	--	--	--	--	--	--	<10	--	<10	--	--	--	<10	--	21
E27	<10	--	--	--	--	--	--	--	<10	--	--	--	--	--	19
E37	76	--	--	82	--	--	--	--	--	--	18	--	--	106	<10
E38	<10	--	--	--	--	--	--	--	--	--	23	--	--	<10	<10
E39	--	--	--	--	--	--	--	--	--	--	20	--	--	<10	<10
GW2	<10	--	--	11	--	--	--	--	--	--	--	--	--	75	--
GW5	--	11	--	--	--	--	--	--	--	--	--	--	--	--	--
GW10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
GZ2	--	--	--	--	--	<10	--	--	--	--	<10	--	--	11	<10
GZ3	--	--	--	--	--	--	<10	--	--	--	11	--	--	20	<10
GZ5	--	--	--	--	--	--	--	--	<10	--	<10	--	--	14	<10
GZ6	--	--	--	--	--	<10	--	--	--	--	12	--	--	10	<10

TABLE 2 - continued

Results of the Organic Analyses of Thirty-two (32) Groundwater Samples from East and North Woburn, Massachusetts
Pesticides
(concentrations in ppb)

Well #	Aldrin	Dieldrin	4,4'-DDT	4,4'-DDE	4,4'-DDD	α-Endosulfan	Heptachlor	Heptachlor epoxide	α-BHC	β-BHC	γ-BHC	δ-BHC
6	--	--	--	--	--	--	--	--	--	--	--	--
364	--	--	--	--	--	--	--	--	--	--	--	--
419	--	--	--	--	--	--	--	--	--	--	--	--
420	--	--	--	--	--	--	--	--	--	--	--	--
424	--	--	--	<5	--	<5	--	--	--	<5	--	--
426	--	--	--	--	--	--	--	--	--	--	--	--
436	--	--	--	--	--	--	--	--	--	--	--	--
439	--	--	--	--	--	--	--	--	--	--	--	--
AG1	--	--	<5	--	--	--	--	--	--	<5	--	<5
AG2	--	--	--	--	--	--	--	--	--	--	--	--
AG4A	--	--	--	--	--	--	--	--	--	--	--	--
AG5	--	--	<5	--	--	--	--	--	<5	--	--	<5
AG6	--	--	--	--	--	--	--	--	--	--	--	<5
AG7	--	--	--	--	--	--	--	<5	--	--	--	--
E3	--	--	--	--	--	--	--	--	--	--	--	--
E8	--	--	--	--	--	--	--	--	--	--	--	--
E9	--	--	--	--	--	--	--	--	--	--	--	--
E11	--	--	--	--	--	--	--	--	--	--	--	--
E11A	--	--	--	--	--	--	--	--	--	--	--	--
E25	<5	<5	--	--	--	--	--	--	<5	--	<5	<5
E26	--	--	--	--	--	--	--	--	--	--	--	--
E27	--	--	--	--	--	--	--	--	--	--	--	--
E37	--	--	<5	<5	--	--	--	--	--	--	--	--
E38	--	--	--	--	<5	--	<5	--	--	<5	<5	<5
E39	--	--	--	--	--	--	--	--	--	<5	--	<5
GW2	<5	--	--	23	--	<5	<5	<5	5	--	--	--
GW5	--	--	--	--	--	--	--	--	--	--	--	--
GW10	--	--	--	--	--	--	--	--	--	--	--	--
GZ2	--	--	<5	--	--	--	--	<5	<5	<5	--	<5
GZ3	--	--	--	--	--	--	--	--	--	--	<5	<5
GZ5	--	--	--	--	<5	--	--	--	--	<5	--	--
GZ6	--	--	<5	<5	--	--	--	<5	<5	<5	--	<5